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DETERIORATION IN THE HEATING VALUE OF COAL DURING STORAGE

BY

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DETERIORATION IN THE HEATING VALUE OF COAL DURING STORAGE.

By HORACE C. PORTER and F. K. OVITZ.

INTRODUCTION.

Much has been written of the changes undergone by coal in storage and the deterioration of coal through exposure to the weather. In order to obtain definite information for the benefit of the Government departments and of all who store coal in large quantities, a series of tests was begun in the fall of 1909 under the supervision of J. A. Holmes, then chief technologist of the United States Geological Survey, and was continued by the Bureau of Mines after its establishment in 1910. The tests were confined to determinations of the loss in heating value of the coals and did not include a study of other deterioration; for example, in coking quality or the yield of by-products in coking. The Bureau of Yards and Docks of the Navy Department cooperated in tests of New River (W. Va.) coal, a variety largely used by the Navy. A preliminary report presenting a brief account of the early results of these tests has been published by the Bureau of Mines as Technical Paper 16.[a]

The detailed report is presented in this bulletin, which gives a full account of the tests and the analytical data covering a period of five years' storage. Data of somewhat similar experiments for shorter periods with gas coal from the Pittsburgh bed, with Pocahontas coal on the Isthmus of Panama, and with Sheridan, Wyo., subbituminous coal, which is used for railroad and other purposes in the West, are included.

The tests of New River coal, in cooperation with the Navy Department, were undertaken to determine the advantage to be gained by storing coal under water, and particularly under salt water. Small lots were used in order to make the tests of maximum severity, and parallel experiments were made with run-of-mine and crushed coal under one-fourth inch size. All of the small lots tested under the different conditions (except those tested near Key West, Fla.) were taken as representative portions from one large original lot.

The tests of Pocahontas coal, which, like the New River, is semibituminous, were undertaken chiefly to determine the effect of the tropical conditions in Panama. They were made on an outdoor pile of 100 tons of run-of-mine coal.

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[a] Porter, H. C., and Ovitz, F. K., Deterioration and spontaneous heating of coal in storage, 1912, 13 pp.

Pittsburgh gas coal, a high-volatile, bituminous type used at gas and by-product coke works, was exposed for test at Ann Arbor, Mich., in cooperation with the University of Michigan. The university agreed to make tests at successive intervals of storage to determine, in its illuminating-gas experiment station, the yields of gas and by-products from the coal. The coal, screened lump, was stored in about 4-ton lots out of doors in open bins.

Subbituminous coal, which is mined in Colorado, Wyoming, and other States, and is known also as "black lignite," is commonly supposed to deteriorate rapidly in storage, especially by "slacking" or crumbling of the lumps. The tests herein described were undertaken at Sheridan, Wyo., in cooperation with the Chicago, Burlington & Quincy Railroad Co., in order to determine the extent of this slacking and the accompanying loss of heat value. The tests were in open bins holding 4 to 12 tons.

GENERAL SUMMARY OF RESULTS.

The results of all these tests are to be taken as showing only the change in heating value and approximately, also, the degradation of lumps by weathering; as to any resultant deadening effect or decrease of original ease of burning, no examination or test was made.

In brief, it may be said, the tests show that the amount of deterioration of coal in heating value during storage has commonly been overestimated. Except for the subbituminous Wyoming coal, no loss was observed in outdoor weathering greater than 1.2 per cent in the first year, or 2.1 per cent in two years. The Wyoming coal suffered somewhat more loss, 2 to 3 per cent in the first year and as much as 5.5 per cent in three years. Details are given under the separate headings.

ACKNOWLEDGMENTS.

Acknowledgment is due to the commandants of the United States navy yards at Portsmouth, N. H., and Norfolk, Va., and of the United States naval station at Key West, Fla., for their cooperation and assistance in the tests on New River coal; to Prof. A. H. White and his assistants at the University of Michigan for carrying out the sampling in the tests of Pittsburgh coals; and to the officials of the Panama Railroad Co., and the Chicago, Burlington & Quincy Railroad Co. for cooperation in the tests of Pocahontas coal and those of Sheridan, Wyo., coal, respectively. The analytical laboratory at the Pittsburgh experiment station of the Bureau of Mines, under the direction of A. C. Fieldner, chemist, performed a large part of the analyses connected with the tests.

TESTS OF NEW RIVER COAL.

Briefly summarized, the tests show that submergence storage of New River coal effectively prevents deterioration of calorific value, and that storage of that coal in the open air causes only slight deterioration, about 1 per cent in one year's exposure and about 2 per cent in two years. After two years, the loss of heating value is continuous but very slow, reaching about 2.5 to 3 per cent in five years. With New River coal, therefore, the expense of underwater storage equipment is not justified except as an absolute preventive of fires from spontaneous combustion.

SOURCE AND PREPARATION OF THE COAL.

The coal used in the tests was from the Sun mine, working the Sewell bed in the New River district, Fayette County, W. Va., and was mined especially for this purpose, under the supervision of a Government mining engineer. An endeavor was made to obtain coal representing the commercial output of the mine.

Small quantities of coal, which in the majority of tests was finely crushed, were used for the express purpose of making the tests of maximum severity and in order to facilitate sampling.

On August 27, 1909, one lot of 3 to 4 tons of run-of-mine coal was collected at the mine and shipped in sacks to Washington, D. C. Three mine samples were taken at the same time from the faces from which the coal was mined, and were mailed at once in sealed cans to the laboratory for analysis. The test coal remained 16 days in the sacks, and then a representative portion, about 2 tons, was crushed to pass a one-fourth-inch screen, mixed well, and divided into small test portions for storing. Each of these portions was reduced by quartering and carefully sampled. Eighteen 50-pound lots of one-fourth-inch coal were placed in heavy wooden boxes for submergence under water. These boxes were lined with canvas and perforated with three-fourths-inch holes to facilitate displacement of the air during submergence. Eight lots of the crushed coal, 300 to 350 pounds each, were placed in barrels. From the balance of the original lot of coal, eight portions, also run-of-mine, were placed in barrels. Each barrel was sampled as thoroughly as possible by taking a number of well-distributed portions of lump and fine, then crushing and reducing these by quartering.

These test portions of coal as prepared in Washington were shipped by freight to the Portsmouth, N. H., and Norfolk, Va., navy yards, and to the experiment station of the Bureau of Mines at Pittsburgh, Pa. Table 1 gives the essential data as to number of portions stored.

On December 14, 1909, another lot of coal was collected from the same mine for storage near Key West, Fla. The mining, preparation, and sampling of the coal were carried out as before, except that a longer time (47 days) elapsed between the mining of the coal and sampling, thereby allowing greater deterioration before the beginning of the tests. Wooden boxes used for the submergence tests near Key West were made of lumber that had been creosoted in order to prevent, if possible, destruction by the teredo. Some of these boxes remained intact, for the purposes of the test, during submergence for three and one-half years.

TABLE 1.—*Conditions of storage of New River, W. Va., coal.*

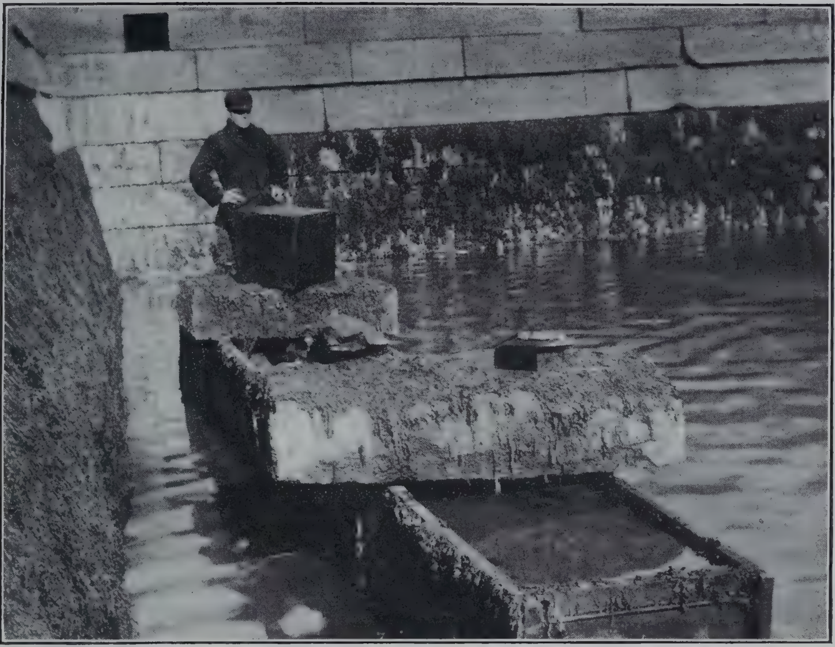
Location of test.	Days between mining and sampling.	Days between sampling and storing.	Size of coal.	Number of portions of—			
				Coal in boxes submerged under sea water.	Coal in barrels submerged under fresh water.	Coal exposed indoors.	Coal exposed outdoors.
Pittsburgh, Pa.	16	34	¼-inch		1	1	2
			Run-of-mine		1	1	2
Portsmouth, N.H.	16	85	¼-inch	9		1	1
			Run-of-mine			1	1
Norfolk, Va.	16	41	¼-inch	9		1	1
			Run-of-mine			1	1
Key West, Fla.	47	27	¼-inch	10		1	1
			Run-of-mine			1	1

STORING THE COAL.

At Pittsburgh, Pa., eight barrels of coal were placed in storage on September 30, 1909, as follows: One barrel of ¼-inch coal and one of run-of-mine were filled with fresh water so as to submerge the coal; one barrel of each grade, dry, was placed indoors loosely covered, and two barrels of each grade were emptied in separate piles, fully exposed to the weather, on the roof of a building at the Bureau of Mines experiment station.

At Portsmouth, N. H., nine boxes and four barrels were placed in storage at the navy yard on November 20, 1909. These test portions had stood at the yard in their closed containers from September 20 to November 20. The nine boxes were placed in a larger box, which was sunk under the full salt water of the dry dock basin until it rested on the granite bottom. (See Pl. I.) The small test boxes were entirely submerged at all times, although the large box containing them was partly out of water at low tide. One barrel of ¼-inch coal and one of run-of-mine, both with heads removed, were placed on a platform in the fire-engine house (see Pl. II, *A*), and one barrel of each grade was emptied in an open pile on the roof of a small shed, where it was fully exposed to the weather (see Pl. II, *B*).

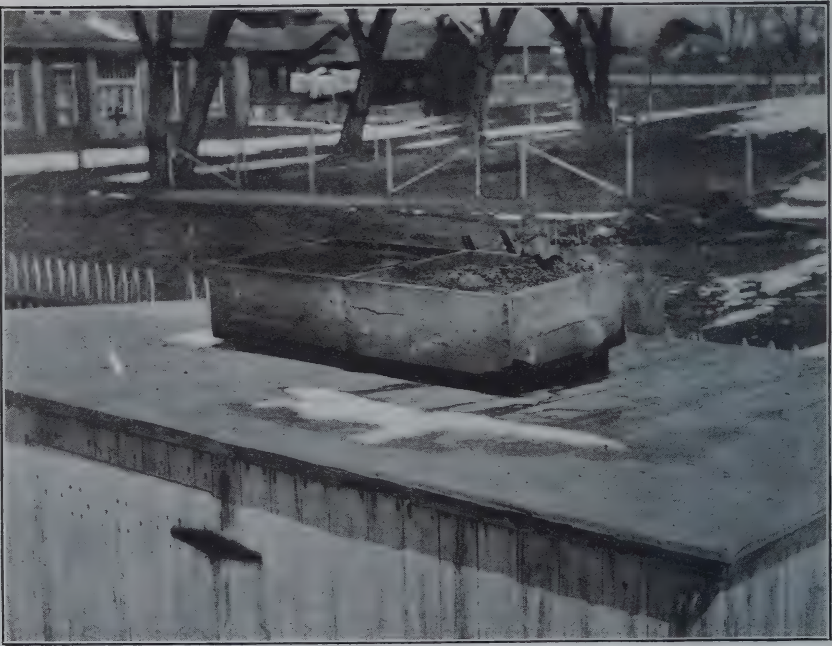
At Norfolk, Va., nine boxes and four barrels were placed in storage at the navy yard on October 7, 1909. The boxes were submerged by chaining them to the pier at a depth insuring complete submer-



A. WEIGHTED BOX CONTAINING SMALLER BOXES OF NEW RIVER COAL SUBMERGED UNDER SALT WATER AT PORTSMOUTH, N. H.

B. DRY-DOCK BASIN, PORTSMOUTH, N. H., WHERE BOXES OF NEW RIVER COAL WERE SUBMERGED.

A. BARRELS OF NEW RIVER COAL EXPOSED INDOORS AT PORTSMOUTH, N. H.



B. NEW RIVER COAL EXPOSED TO WEATHER AT PORTSMOUTH, N. H.

gence at all tides (see Pl. III, *A*). The portions for open-air tests indoors were emptied from the barrels into open boxes on platforms, especially made for the purpose inside of one of the navy yard buildings (see Pl. III, *C*); and the outdoor open-air tests were similarly arranged outside one of the buildings (see Pl. III, *B*).

Near Key West, Fla., the test portions were placed in storage at Fort Jefferson, Dry Tortugas, on February 25, 1910, a special lot of coal having been collected for them nearly four months after the collection of the first lot. Ten creosoted boxes were submerged in the moat, one barrel of each grade was placed indoors in a casemate, and one of each set was put outside on the parapet, exposed to the weather. Two months later, on April 25, the outside test portions were emptied from the barrels into open piles. Early in January, 1911, 10 months after storing, the open-air test piles were scattered by a storm and lost. The two barrels that had been stored indoors were then emptied into outdoor piles to replace those lost.

At Portsmouth, N. H., the tests were under the immediate supervision of U. S. G. White, civil engineer, United States Navy, during the first few months of their progress, and of L. E. Gregory, civil engineer, United States Navy, thereafter. At Dry Tortugas, Fla., they were carried out by George C. Short, mate, United States Navy, under the direction of the commandant of the station. At Norfolk, Va., a representative of the Government fuel inspection service directed the starting of the tests and the subsequent sampling.

SAMPLING THE COAL.

Samples of each portion were taken periodically and the successive analyses were compared separately. During the first year, samples were taken every three months, during the second year every six months, and thereafter every year. The submerged boxes were sampled in rotation; that is, at three months box 1 was sampled, at six months box 2, and so on, in order to avoid repeated exposure of the coal. In addition, one particular box was repeatedly sampled in order to determine the effect, if any, of this periodical exposure on the deterioration. Thus at each sampling time two boxes were raised from the water, one was immediately replaced, the other was emptied. The wet coal in the latter was spread out in the open air for 24 hours, then sampled and replaced.

The submerged fine coal was sampled by the customary quartering method, the entire lot being spread out and reduced, by repeated quartering and rejection of alternate quarters, to a sample of convenient size for mailing, about 2 to 3 pounds. The barrel lots exposed to the air were not sampled in the same way because the coal would thus have been repeatedly turned over at each sampling time and unduly exposed as compared with usual storage conditions. Instead, samples were taken by selecting at random six or eight well-distributed portions of 2 pounds each, then mixing and quartering them. From the run-of-mine coal, half of these selected portions were pieces broken from lumps, the balance being from the finer coal. Before quartering, all lumps were crushed to ½-inch size. In most cases duplicate samples were taken from each lot.

ANALYSIS OF THE COAL SAMPLES.

All coal samples taken during the first two years' progress of the tests were analyzed at the laboratory of the Pittsburgh experiment station, the calorimetric determinations being made throughout by the same man and with the same calorimeter. Each sample was analyzed for moisture, ash, and sulphur, and its calorific value determined. A number of composite samples were subjected to a complete ultimate analysis for carbon, hydrogen, oxygen, nitrogen, and sulphur. The methods used were those described in Technical Paper 8[a] of the bureau.

"UNIT COAL" THE BASIS OF COMPARISON OF VALUES.

In studying the deterioration of coal the important practical problem is to determine the change in the dry organic substance. The incidental ingredients—sulphur, ash, and moisture—that accompany the coal substance affect the calorific value of a coal, but any changes that they may undergo have nothing to do with the alteration of the coal substance itself. For example, a coal wetted by exposure has its apparent calorific value reduced through the addition of water, whereas on the basis of dry material its fuel value may be unaltered. Furthermore, as to ash and sulphur, it is not practicable, by use of the sampling methods adopted in these tests, to obtain from the same lot of coal, even in ¼-inch size, successive samples in which the aggregate percentages of these ingredients will always agree within 0.5 per cent. In other words, determination of calorific values of a stored coal might seem to show a deterioration of, say, 0.5 per cent, when in fact all of this change could be accounted for by the different moisture or ash content of the samples.

This investigation, therefore, endeavors to show merely the extent of deterioration in the actual coal substance, which in this paper is termed "unit coal." The calorific values as determined are all reduced to this basis—eliminating the effect of moisture, ash, and sulphur—by the following formula;

$$W=\frac{w-2620S}{1.00-[(M+A+\frac{5}{8}S+0.04\,(A-\frac{10}{8}S)]}$$

in which W = calories on unit coal basis, w = determined calories, M = moisture, A = ash, and S = sulphur.

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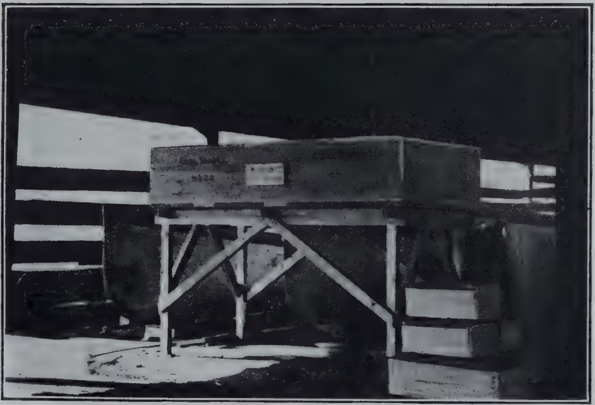
[a] Stanton, F. M., and Fieldner, A. C., Methods of analyzing coal and coke: Tech. Paper 8, Bureau of Mines, 1913, 42 pp.

A. DOCK UNDER WHICH BOXES OF NEW RIVER COAL WERE SUBMERGED AT NORFOLK, VA.

Black cross indicates spot under which boxes were chained to the piles.

B. OUTDOOR EXPOSURE OF NEW RIVER COAL AT NORFOLK, VA.



C. EXPOSURE OF NEW RIVER COAL UNDER SHELTER AT NORFOLK, VA.

As sulphur has a positive calorific value, its theoretical heat of combustion when in the form of iron pyrites, 2,620 calories, is subtracted from the determined calorific value. The expression below the line in the formula represents the percentage of "unit coal" in the sample, the moisture, ash, and sulphur being subtracted from 100 per cent. The expression, $A+\frac{5}{8}S+0.04\ (A-\frac{10}{8}S)$ is based on the assumption that all the sulphur is present as FeS_2 (iron pyrites) and that therefore the ash content determined must be corrected for the decrease in weight due to burning FeS_2 to Fe_2O_3—this decrease being five-eighths of the sulphur—and on the further assumption that the ash as determined is less than the true original ash by the amount of combined water driven out of clay and shale, roughly 4 per cent of the pyrite-free ash. These assumptions are based on a chemical examination of the shale and sulphur partings of the coal bed in the mine from which this coal was obtained.

WEATHER CONDITIONS.

Weather conditions varied at the different storage points, the tests being more severe at Key West and Norfolk than at Portsmouth and Pittsburgh. Table 2 shows average temperature conditions in air and water at the different points throughout the first two years of the tests.

TABLE 2.—*Monthly temperature averages (°F.) of air and water.*

[P.=Portsmouth, N. H.: Pgh.=Pittsburgh; N.=Norfolk; K. W.=Key West (Dry Tortugas).]

Month.	Temperature of air.								Temperature of water.			
	Average.				Maximum.				Average.			
	P.	Pgh.	N.	K.W.	P.	Pgh.	N.	K. W.	P.	Pgh.[a]	N.	K. W.[b]
1909.												
October	51.1	49.6	58.4	77.4	85	80	79	88	......	85	......	78
November	43.5	50.4	55.0	73.4	72	73	76	82	......	90	57	77
December	28.6	26.8	38.8	69.2	52	65	64	81	......	60	42	71
1910.												
January	28.5	30.8	41.6	67.1	51	51	69	80	......	55	43	68
February	25.4	28.6	43.2	69.0	54	55	76	81	......	55	41	67
March	39.4	48.8	55.0	71.3	74	83	90	81	39	60	51	69
April	48.5	52.8	60.0	74.2	68	83	87	83	47	65	60	72
May	55.8	57.8	65.2	78.4	78	83	90	87	50	70	66	77
June	65.4	67.0	72.0	81.9	90	90	92	89	57	75	74	81
July	74.7	74.9	78.4	82.8	94	91	93	90	61	75	81	82
August	69.4	72.8	76.4	83.1	90	90	90	92	60	73	81	83
September	62.7	67.6	73.4	81.4	83	86	92	90	59	70	77	82
October	54.6	57.6	63.8	77.8	87	84	86	87	53	70	70	79
November	40.9	37.1	45.4	70.4	59	63	71	79	46	65	49	73
December	26.2	27.0	37.2	65.3	51	55	66	78	37	60	39	70
1911.												
January	28.3	35.2	45.0	70.3	56	60	72	80	35	60	42	66
February	24.0	35.3	43.8	71.5	46	64	71	82	33	60	45	67
March	32.8	37.1	47.0	73.5	55	66	77	84	36	65	47	69
April	44.7	48.1	54.6	77.1	83	78	80	85	40	65	56	75
May	61.9	68.0	69.2	77.6	99	93	94	86	49	65	68	77
June	65.1	71.0	75.6	81.8	93	94	98	89	56	70	77	80
July	76.6	75.4	79.2	82.2	106	100	97	90	60	75	83	83
August	69.3	73.8	78.8	82.0	93	97	94	90	58	75	81	83
September	62.0	68.0	74.4	82.5	87	86	88	90	56	70	79	82
October	52.0	54.2	62.6	81.8	73	77	89	89	50	70	68	81

[a] Estimated. The barrels of coal were transferred in December, 1909, from a warm room to a cooler one.
[b] Estimated, except in January, April, and July, 1911, when observations were made on single days.

RESULTS OF STORAGE TESTS.

Results of storage tests are shown in Tables 3 to 16 following:

TABLE 3.—*Storage tests of New River, W. Va., coal, ¼-inch crushed, submerged under sea water, at Portsmouth, N. H., in 50-pound portions.*

	Date sampled.	Number of samples averaged.	Moisture.	Analysis on dry basis.				Heating value on "unit coal" basis.		
				Ash.	Sulphur.	Calories.	B. t. u.	Calories.	B. t. u.	Loss in B.t.u.
			P. ct.	*P. ct.*	*P. ct.*					*P. ct.*
Mine sample	Aug. 27, 1909	3	3.46	3.50	0.66	8,438	15,188	8,773	15,792	......
As stored:										
Box 1	Sept. 12, 1909	2	1.98	4.03	.74	8,361	15,050	8,747	15,745	......
2	do	2	1.84	4.39	.76	8,343	15,018	8,763	15,774	......
3	do	2	2.07	5.99	.93	8,183	14,729	8,750	15,750	......
4	do	2	2.14	5.00	.78	8,288	14,918	8,761	15,770	......
5	do	2	2.18	5.14	.92	8,277	14,899	8,769	15,784	......
6	do	2	1.92	4.27	.76	8,357	15,043	8,764	15,775	......
7	do	2	1.39	4.88	.76	8,298	14,936	8,759	15,767	......
8	do	2	1.79	5.89	.94	8,196	14,752	8,755	15,759	......
9	do	2	1.72	4.75	.88	8,298	14,937	8,752	15,754	......
After 4 months:										
Box 1	Jan. 3, 1910	1	19.77	7.60	2.28	7,986	14,375	8,730	15,714	0.2
After 6 months:										
Box 2	Apr. 15, 1910	1	14.83	6.21	.95	8,113	14,603	8,700	15,660	.7
9	do	2	5.65	5.84	.91	8,167	14,701	8,715	15,687	.4
After 9 months:										
Box 3	July 19, 1910	1	16.68	6.27	.90	8,151	14,672	8,744	15,739	.1
9	do	2	14.74	4.76	.80	8,300	14,939	8,751	15,752	......
After 1 year:										
Box 4	Oct. 11, 1910	2	17.42	4.33	.75	8,347	15,025	8,759	15,765	......
9	do	2	13.71	3.94	.71	8,396	15,112	8,773	15,791	[a].2
After 1½ years:										
Box 5	Apr. 7, 1911	2	19.91	7.08	1.28	8,047	14,485	8,724	15,703	.5
9	do	2	17.57	6.52	1.01	8,095	14,571	8,711	15,680	.5
After 2 years:										
Box 6	Oct. 10, 1911	1	16.01	5.54	.83	8,201	14,762	8,724	15,703	.5
9	do	2	18.72	6.60	.94	8,111	14,599	8,733	15,719	.2
After 3 years:										
Box 7	Oct. 17, 1912	2	18.39	5.97	1.01	8,134	14,641	8,698	15,614	1.0
9	do	1	22.22	7.37	1.14	7,958	14,324	8,648	15,566	1.2
After 4 years:										
Box 8	Oct. 6, 1913	2	17.72	7.40	1.19	8,019	14,434	8,718	15,692	.4
9	do	2	21.58	8.34	1.17	7,909	14,236	8,689	15,640	.6
After 5 years:										
Box 8	Oct. 17, 1914	2	17.93	8.49	1.30	7,922	14,259	8,723	15,701	.4

[a] Gain.

TABLE 4.—*Storage tests of New River, W. Va., coal, exposed indoors at Portsmouth, N. H., in 350-pound portions.*

	Date sampled.	Number of samples averaged.	Moisture.	Analysis on dry basis.				Heating value on "unit coal" basis.		
				Ash.	Sulphur.	Calories.	B. t. u.	Calories.	B. t. u.	Loss in B.t.u.
Run of mine coal:			*P. ct.*	*P. ct.*	*P. ct.*					*P. ct.*
As stored	Sept. 12, 1909	2	1.75	4.45	0.69	8,332	14,998	8,574	15,757	......
After 3 months	Jan. 3, 1910	1	.67	4.82	1.33	8,282	14,908	8,753	15,755	0.0
1 year	Oct. 11, 1910	2	1.19	2.94	.46	8,469	15,254	8,748	15,746	.1
1½ years	Apr. 7, 1911	2	.70	6.28	1.28	8,115	14,606	8,713	15,683	.5
2 years	Oct. 10, 1911	2	1.01	3.98	.74	8,350	15,029	8,728	15,710	.3
3 years	Oct. 11, 1912	2	.98	5.34	1.09	8,168	14,703	8,675	15,615	.9
4 years	Oct. 8, 1913	2	.98	6.25	1.33	8,085	14,553	8,681	15,625	.8
5 years	Oct. 17, 1914	2	1.15	5.73	.94	8,124	14,623	8,663	15,593	1.0
¼-inch crushed coal:										
As stored	Sept. 12, 1909	2	1.79	6.27	.84	8,185	14,733	8,779	15,802	......
After 3 months	Jan. 3, 1910	1	.92	7,82	.94	7,966	14,339	8,724	15,703	.6
1 year	Oct. 11, 1910	2	1.22	5.64	.70	8,213	14,783	8,742	15,736	.4
1½ years	Apr. 7, 1911	2	.79	6.68	.86	8,096	14,572	8,721	15,679	.7
2 years	Oct. 10, 1911	2	1.23	7.14	.97	8,034	14,460	8,703	15,666	.9
3 years	Oct. 11, 1912	2	1.02	6.42	.94	8,067	14,521	8,667	15,601	1.3
4 years	Oct. 8, 1913	2	1.04	6.93	1.01	7,995	14,391	8,641	15,554	1.6
5 years	Oct. 17, 1914	2	1.19	6.84	1.02	8,012	14,422	8,652	15,573	1.4

TABLE 5.—*Storage tests of New River, W. Va., coal exposed to weather at Portsmouth, N. H., in 350-pound portions.*

	Date sampled.	Number of samples averaged.	Moisture.	Analysis on dry basis.				Heating value on "unit coal" basis.		
				Ash.	Sulphur.	Calories.	B. t. u.	Calories.	B. t. u.	Loss in B.t.u.
Run-of-mine coal:			*P. ct.*	*P. ct.*	*P. ct.*					*P. ct.*
As stored	Sept. 12, 1909	2	1.81	5.34	0.70	8,271	14,888	8,775	15,795	......
After 3 months	Jan. 3, 1910	1	3.22	4.89	1.23	8,282	14,908	8,757	15,763	0.2
6 months	Apr. 15, 1910	1	1.44	2.67	.52	8,486	15,275	8,742	15,736	.4
9 months	July 19, 1910	2	1.38	5.02	.64	8,265	14,876	8,738	15,725	.4
1 year	Oct. 11, 1910	2	2.32	2.20	.34	8,551	15,392	8,760	15,768	.2
1½ years	Apr. 7, 1911	2	2.43	2.41	.52	8,507	15,313	8,738	15,728	.4
2 years	Oct. 10, 1911	2	2.33	3.61	.38	8,378	15,080	8,716	15,688	.7
3 years	Oct. 11, 1912	2	4.50	3.67	.71	8,333	14,999	8,681	15,625	1.1
4 years	Oct. 7, 1913	2	3.07	4.18	.62	8,293	14,928	8,684	15,632	1.0
5 years	Oct. 17, 1914	2	3.45	3.53	.54	8,318	14,973	8,648	15,567	1.4
¼-inch crushed coal:										
As stored	Sept. 12, 1909	2	2.01	6.68	1.02	8,116	14,609	8,748	15,747	......
After 3 months	Jan. 3, 1910	2	3.10	7.29	1.27	8,028	14,451	8,720	15,695	.3
6 months	Apr. 15, 1910	1	2.00	6.48	1.03	8,111	14,600	8,726	15,707	.3
9 months	July 19, 1910	2	1.93	6.70	1.07	8,085	14,553	8,719	15,694	.3
1 year	Oct. 11, 1910	2	3.75	6.94	.94	8,051	14,491	8,701	15,661	.5
1½ years	Apr. 7, 1911	2	10.50	6.67	1.00	8,059	14,506	8,685	15,633	.7
2 years	Oct. 10, 1911	2	17.42	7.04	.75	8,016	14,429	8,668	14,603	.9
3 years	Oct. 11, 1912	2	12.86	6.91	.92	7,995	14,390	8,637	15,547	1.3
4 years	Oct. 7, 1913	2	16.23	6.90	.72	8,004	14,407	8,641	15,553	1.2
5 years	Oct. 17, 1914	2	13.09	7.92	.77	7,908	14,234	8,637	15,547	1.3

TABLE 6.—*Storage tests of New River, W. Va., coal, ¼-inch crushed, submerged under sea water at Norfolk, Va., in 50-pound portions.*

	Date sampled.	Number of samples averaged.	Moisture.	Analysis on dry basis.				Heating value on "unit coal" basis.		
				Ash.	Sulphur.	Calories.	B. t. u.	Calories.	B. t. u.	Loss in B.t.u.
As stored:			*P. ct.*	*P. ct.*	*P. ct.*					*P. ct.*
Box 10	Sept. 12, 1909	2	2.00	5.20	0.96	8,272	14,891	8,772	15,790	......
11	do	2	2.01	6.45	.99	8,130	14,635	8,742	15,736	......
12	do	2	1.99	5.13	.82	8,260	14,867	8,744	15,739	......
13	do	2	1.80	5.42	.93	8,237	14,827	8,754	15,757	......
14	do	2	1.64	5.44	1.03	8,234	14,821	8,754	15,757	......
15	do	2	1.86	5.22	.81	8,269	14,894	8,764	15,775	......
16	do	2	1.64	5.12	.70	8,262	14,872	8,745	15,741	......
17	do	2	1.80	5.33	.88	8,239	14,831	8,745	15,740	......
After 3 months:										
Box 10	Jan. 11, 1910	2	17.54	5.82	1.05	8,191	14,744	8,747	15,745	0.3
After 6 months:										
Box 10	Apr. 7, 1910	2	10.47	5.72	.99	8,190	14,743	8,733	15,720	.4
11	do	1	15.52	6.34	1.11	8,140	14,653	8,744	15,739	.0
After 10 months:										
Box 10	July 13, 1910	2	18.06	5.35	.92	8,248	14,846	8,757	15,763	.2
12	do	1	16.62	4.56	.74	8,310	14,958	8,744	15,739	.0
After 1 year:										
Box 10	Oct. 4, 1910	2	14.94	5.72	.95	8,193	14,748	8,737	15,725	.4
13	do	1	17.35	4.34	.82	8,345	15,021	8,763	15,773	[a] .1
After 1½ years:										
Box 10	Apr. 4, 1911	2	20.63	6.67	1.13	8,105	14,588	8,738	15,729	.4
14	do	1	19.71	6.69	1.28	8,114	14,605	8,756	15,761	.0
After 2 years:										
Box 10	Oct. 4, 1911	2	18.92	8.01	1.12	7,968	14,344	8,719	15,695	.6
15	do	1	20.47	6.55	.93	8,108	14,593	8,725	15,705	.4
After 3 years:										
Box 10	Oct. 15, 1912	2	24.16	11.03	1.27	7,641	13,753	8,663	15,594	1.2
16	do	1	16.46	6.92	.97	8,047	14,485	8,696	15,653	.6
After 4 years:										
Box 17	Oct. 10, 1913	1	20.98	6.77	1.08	8,069	14,524	8,708	15,674	.4
After 5 years:										
Box 17	Oct. 8, 1914	1	24.62	7.91	1.15	7,957	14,323	8,701	15,662	.5

[a] Gain.

TABLE 7.—*Storage tests of New River, W. Va., coal exposed indoors at Norfolk, Va., in 350-pound portions.*

	Date sampled.	Number of samples averaged.	Moisture.	Analysis on dry basis.				Heating value on "unit coal" basis.		
				Ash.	Sulphur.	Calories.	B. t. u.	Calories.	B. t. u.	Loss in B.t.u.
Run-of-mine coal:			*P. ct.*	*P. ct*	*P. ct.*					*P. ct.*
As stored	Sept. 12, 1909	2	1.61	4.14	0.77	8,348	15,027	8,743	15,737	......
After 3 months	Jan. 11, 1910	1	1.37	4.39	.65	8,349	15,029	8,764	15,775	[a] 0.2
6 months	Apr. 7, 1910	2	1.14	3.93	.65	8,367	15,061	8,739	15,729	.1
9 months	July 13, 1910	2	1.43	5.60	.84	8,202	14,762	8,732	15,718	.1
1 year	Oct. 4, 1910	2	1.47	5.10	.71	8,246	14,843	8,725	15,705	.2
1½ years	Apr. 4, 1911	2	1.49	4.70	.73	8,282	14,658	8,727	15,709	.2
2 years	Oct. 4, 1911	2	1.33	5.35	.75	8,221	14,798	8,724	15,703	.2
3 years	Oct. 15, 1912	2	4.67	5.18	.88	8,207	14,773	8,696	15,653	.5
4 years	Oct. 11, 1913	2	1.81	4.20	.74	8,287	14,917	8,684	15,631	.7
5 years	Oct. 8, 1914	2	1.83	6.01	.87	8,110	14,598	8,673	15,612	.8
¼-inch crushed coal—										
As stored	Sept. 12, 1909	2	1.78	5.67	.85	8,216	14,787	8,751	15,752	......
After 3 months	Jan. 11, 1910	1	1.52	5.88	.79	8,188	14,739	8,742	15,736	.1
6 months	Apr. 7, 1910	2	1.28	6.02	.73	8,157	14,683	8,718	15,696	.4
9 months	July 13, 1910	2	1.54	5.71	.69	8,189	14,740	8,725	15,705	.3
1 year	Oct. 4, 1910	2	1.70	5.63	.64	8,208	14,774	8,736	15,724	.2
1½ years	Apr. 4, 1911	2	1.60	5.88	.69	8,160	14,687	8,708	15.674	.5
2 years	Oct. 4, 1911	2	1.54	6.04	.74	8,153	14,674	8,718	15,692	.4
3 years	Oct. 15, 1912	2	4.54	6.66	.88	8,041	14,473	8,661	15,590	1.0
4 years	Oct. 11, 1913	2	1.73	7.14	.82	7,986	14,375	8,647	15,565	1.2
5 years	Oct. 8, 1914	2	2.06	6.84	.82	8,011	14,420	8,646	15,562	1.2

[a] Gain.

TABLE 8.—*Storage tests of New River, W. Va., coal exposed to weather at Norfolk, Va., in 350-pound portions.*

	Date sampled.	Number of samples averaged.	Moisture.	Analysis on dry basis.				Heating value on "unit coal" basis.		
				Ash.	Sulphur.	Calories.	B. t. u.	Calories.	B. t. u.	Loss in B.t.u.
Run-of-mine coal:			*P. ct.*	*P. ct.*	*P. ct.*					*P. ct.*
As stored	Sept. 12, 1909	2	1.74	3.63	0.58	8,397	15,115	8,743	15,738	......
After 3 months	Jan. 11, 1910	2	3.04	4.20	.74	8,345	15,021	8,745	15,741	0.0
6 months	Apr. 7, 1910	2	3.30	4.76	.65	8,283	14,909	8,732	15,717	.1
9 months	July 13, 1910	2	2.06	4.41	.59	8,336	15,004	8,752	15,754	[a] .1
1 year	Oct. 4, 1910	2	2.06	5.19	.68	8,209	14,817	8,720	15,695	.3
1½ years	Apr. 4, 1911	2	9.90	5.05	.52	8,258	14,865	8,729	15,711	2
2 years	Oct. 4, 1911	2	3.44	5.77	.65	8,157	14,683	8,695	15,650	.6
3 years	Oct. 15, 1912	2	6.80	5.41	.64	8,158	14,684	8,660	15,587	1.0
4 years	Oct. 11, 1913	2	6.25	4.60	.61	8,209	14,776	8,637	15,546	1.2
5 years	Oct. 8, 1914	2	6.59	6.19	.63	8,075	14,535	8,646	15,563	1.1
¼-inch crushed coal:										
As stored	Sept. 12, 1909	2	2.04	7.97	1.00	7,977	14,358	8,725	15,704	......
After 3 months	Jan. 11, 1910	2	4.26	8.61	1.11	7,907	14,233	8,715	15,686	.1
6 months	Apr. 7, 1910	2	5.83	9.93	1.04	7,784	14,010	8,708	15,675	.2
9 months	July 13, 1910	2	1.48	8.45	.95	7,910	14,237	8,698	15,657	.3
1 year	Oct. 4, 1910	2	1.80	8.89	.93	7,843	14,118	8,666	15,598	.7
1½ years	Apr. 4, 1911	2	14.38	9.52	.91	7,785	14,013	8,664	15,594	.7
2 years	Oct. 4, 1911	2	5.38	10.84	.90	7,631	13,734	8,624	15,522	1.2
3 years	Oct. 15, 1912	2	13.48	10.83	.85	7,606	13,691	8,594	15,469	1.5
4 years	Oct. 11, 1913	2	11.92	12.49	.73	7,437	13,386	8,567	15,420	1.8
5 years	Oct. 8, 1914	2	15.72	10.62	.71	7,647	13,764	8,614	15,505	1.3

[a] Gain.

TABLE 9.—*Storage tests of New River, W. Va., coal submerged in fresh water at Pittsburgh, Pa., in 350-pound portions.*

	Date sampled.	Number of samples averaged.	Moisture.	Analysis on dry basis.				Heating value on "unit coal" basis.		
				Ash.	Sulphur.	Calories.	B. t. u.	Calories.	B. t. u.	Loss in B.t.u.
Run-of-mine coal:			*P. ct.*	*P. ct.*	*P. ct.*					*P. ct.*
As stored	Sept. 12, 1909	2	1.61	5.08	0.96	8,269	14,885	8,756	15,761	......
After 3 months	Jan. 22, 1910	1	8.11	7.17	.95	8,072	14,530	8,748	15,746	0.1
6 months	Apr. 8, 1910	1	10.72	5.50	.76	8,230	14,814	8,752	15,754	.0
9 months	July 8, 1910	2	7.88	5.96	1.23	8,197	14,754	8,770	15,786	[a] .2
1 year	Oct. 7, 1910	2	8.97	6.11	1.15	8,175	14,715	8,762	15,771	[a] .1
1½ years	Apr. 13, 1911	2	9.65	5.18	1.04	8,256	14,860	8,751	15,751	.1
2 years	Oct. 9, 1911	2	12.09	7.36	.98	8,075	14,534	8,769	15,784	[a] .1
3 years	Oct. 4, 1912	2	7.32	5.60	1.24	8,170	14,706	8,707	15,672	.6
4 years	Oct. 7, 1913	2	8.96	5.89	1.01	8,184	14,730	8,743	15,737	.2
5 years	Oct. 15, 1914	2	10.83	9.30	2.41	7,844	14,119	8,749	15,747	.1
¼-inch crushed coal:										
As stored	Sept. 12, 1909	2	1.58	4.83	.64	8,299	14,939	8,752	15,754	......
After 3 months	Jan. 22, 1910	1	18.04	5.28	.68	8,263	14,873	8,762	15,772	[a] .1
6 months	Apr. 8, 1910	1	23.62	5.47	.68	8,224	14,804	8,740	15,732	.1
9 months	July 8, 1910	2	19.64	5.18	.64	8,268	14,882	8,756	15,761	.0
1 year	Oct. 7, 1910	2	20.04	5.35	.61	8,245	14,841	8,747	15,744	.1
1½ years	Apr. 13, 1911	2	23.44	5.27	.64	8,248	14,847	8,743	15,738	.1
2 years	Oct. 9, 1911	2	19.78	5.69	.67	8,220	14,795	8,754	15,757	.0
3 years	Oct. 4, 1912	2	18.82	5.62	.75	8,163	14,693	8,663	15,639	.7
4 years	Oct. 7, 1913	1	20.26	5.84	.74	8,192	14,746	8,741	15,734	.1
5 years	Oct. 15, 1914	2	21.76	6.23	.80	8,160	14,687	8,745	15,741	.1

[a] Gain.

TABLE 10.—*Storage tests of New River, W. Va., coal exposed indoors at Pittsburgh, Pa., in 350-pound portions.*

	Date sampled.	Number of samples averaged.	Moisture.	Analysis on dry basis.				Heating value on "unit coal" basis.		
				Ash.	Sulphur.	Calories.	B. t. u.	Calories.	B. t. u.	Loss in B.t.u.
Run-of-mine coal:			*P. ct.*	*P. ct.*	*P. ct.*					*P. ct.*
As stored	Sept. 12, 1909	2	1.82	5.09	0.76	8,271	14,887	8,753	15,756	......
After 3 months	Jan. 22, 1910	1	.89	3.91	.72	8,383	15,089	8,758	15,764	0.1
6 months	Apr. 8, 1910	2	.92	4.31	.89	8,301	14,942	8,715	15,687	.4
9 months	July 8, 1910	2	1.19	4.10	.71	8,360	15,047	8,750	15,749	.0
1 year	Oct. 7, 1910	2	1.43	4.63	.66	8,280	14,903	8,741	15,733	.1
1½ years	Apr. 13, 1911	2	.87	6.71	1.52	8,072	14,530	8,717	15,690	.4
2 years	Oct. 9, 1911	2	1.62	5.54	.74	8,216	14,789	8,737	15,727	.2
3 years	Oct. 4, 1912	2	1.80	3.60	.54	8,323	14,982	8,659	15,586	1.1
4 years	Oct. 7, 1913	2	1.83	4.40	.92	8,253	14,856	8,671	15,608	.9
5 years	Oct. 15, 1914	2	2.23	5.01	1.07	8,219	14,794	8,698	15,656	.6
¼-inch crushed coal:										
As stored	Sept. 12, 1909	2	1.68	6.08	1.04	8,189	14,740	8,769	15,787	......
After 3 months	Jan. 22, 1910	1	2.72	6.69	1.19	8,103	14,585	8,740	15,732	.3
6 months	Apr. 8, 1910	2	.99	6.52	1.12	8,109	14,596	8,727	15,709	.5
9 months	July 8, 1910	2	1.39	6.12	1.01	8,152	14,673	8,733	15,719	.4
1 year	Oct. 7, 1910	2	1.48	6.68	.93	8,091	14,564	8,719	15,693	.6
1½ years	Apr. 13, 1911	2	1.08	6.64	1.11	8,068	14,523	8,695	15,650	.9
2 years	Oct. 9, 1911	2	4.14	8.83	1.03	7,888	14,198	8,714	15,685	.6
3 years	Oct. 4, 1912	2	2.99	10.27	1.20	7,678	13,820	8,626	15,527	1.6
4 years	Oct. 7, 1913	1	2.50	8.55	1.16	7,834	14,101	8,629	15,532	1.6
5 years	Oct. 15, 1914	2	2.81	9.25	1.20	7,763	13,974	8,620	15,515	1.7

TABLE 11.—*Storage tests of New River, W. Va., coal exposed to weather at Pittsburgh, Pa., in 350-pound portions.*

	Date sampled.	Number of samples averaged.	Moisture.	Analysis on dry basis.				Heating value on "unit coal" basis.		
				Ash.	Sulphur.	Calories.	B. t. u.	Calories.	B. t. u.	Loss in B.t.u
			P. ct.	*P. ct.*	*P. ct.*					*P. ct.*
Run-of-mine coal:										
As stored	Sept. 12, 1909	4	1.14	4.04	0.59	8,370	15,066	8,752	15,754	......
After 3 months	Jan. 24, 1910	2	4.39	7.69	1.46	8,007	14,412	8,740	15,732	0.1
6 months	Apr. 22, 1910	2	2.35	6.21	.71	8,126	14,627	8,704	15,667	.6
9 months	July 12, 1910	2	1.49	4.24	.62	8,348	15,026	8,749	15,748	.0
1 year	Oct. 14, 1910	2	1.86	5.01	.70	8,245	14,841	8,716	15,689	.4
1½ years	Apr. 20, 1911	4	3.78	6.08	.89	8,136	14,646	8,708	15,674	.5
2 years	Oct. 12, 1911	2	4.85	8.28	.78	7,923	14,261	8,690	15,642	.7
3 years	Oct. 7, 1912	2	2.32	5.85	.89	8,096	14,573	8,642	15,555	1.3
4 years	Oct. 8, 1913	2	3.09	5.20	.61	8,178	14,721	8,661	15,589	1.0
5 years	Oct. 13, 1914	2	4.26	8.43	.62	7,877	14,179	8,650	15,570	1.2
¼-inch crushed coal:										
As stored	Sept. 12, 1909	4	1.29	7.45	.91	8,052	14,494	8,752	15,754	......
After 3 months	Jan. 24, 1910	2	14.02	8.75	1.22	7,904	14,227	8,726	15,707	.3
6 months	Apr. 22, 1910	2	1.71	7.23	1.15	8,014	14,426	8,695	15,651	.7
9 months	July 12, 1910	2	1.22	7.79	1.05	7,971	14,348	8,701	15,662	.6
1 year	Oct. 14, 1910	2	1.99	8.33	1.06	7,918	14,253	8,697	15,655	.6
1½ years	Apr. 20, 1911	4	6.67	9.49	1.27	7,798	14,036	8,685	15,632	.8
2 years	Oct. 12, 1911	2	10.88	9.31	1.18	7,792	14,026	8,659	15,586	1.1
3 years	Oct. 7, 1912	2	2.92	8.75	.98	7,805	14,049	8,612	15,502	1.6
4 years	Oct. 8, 1913	2	6.36	8.60	.82	7,827	14,088	8,616	15,509	1.6
5 years	Oct. 13, 1914	1	11.67	7.19	.62	7,975	14,355	8,637	15,547	1.3

TABLE 12.—*Storage tests of New River, W. Va., coal, ¼-inch crushed, submerged in sea water at Key West (Dry Tortugas), Fla., in 50-pound portions.*

	Date sampled.	Number of samples averaged.	Moisture.	Analysis on dry basis.				Heating value on "unit coal" basis.		
				Ash.	Sulphur.	Calories.	B. t. u.	Calories.	B. t. u.	Loss in B.t.u.
			P. ct.	*P. ct.*	*P. ct.*					*P. ct.*
Mine sample	Dec. 15, 1909	2	3.20	7.26	1.99	8,053	14,495	8,761	15,770	......
As stored:										
Box 35	Jan. 29, 1910	2	.79	7.09	2.13	8,045	14,480	8,742	15,735	......
36	do	2	1.02	6.55	.81	8,108	14,593	8,722	15,700	......
37	do	2	.89	4.10	.82	8,362	15,052	8,755	15,759	......
38	do	2	1.06	3.24	.81	8,434	15,180	8,747	15,745	......
39	do	2	1.02	3.96	.74	8.388	15,099	8,766	15,779	......
40	do	2	.92	5.21	.80	8,253	14,856	8,745	15,741	......
41	do	2	.96	4.87	.89	8,282	14,908	8,746	15,743	......
42	do	2	.97	4.41	.83	8,335	15,003	8,757	15,763	......
43	do	2	.97	5.92	.95	8,180	14,723	8,739	15,730	......
44	do	2	1.02	5.73	.90	8,193	14,747	8,734	15,721	......
After 3 months:										
Box 35	Apr. 26, 1910	2	7.74	6.23	1.32	8,126	14,626	8,723	15,702	0.2
36	do	2	9.59	6.31	.82	8,116	14,638	8,706	15,671	.2
After 6 months:										
Box 35	July 14, 1910	2	17.84	6.70	1.46	8,088	14,559	8,731	15,716	.1
37	do	2	11.93	7.33	.88	8,027	14,449	8,712	15,681	.5
After 8 months:										
Box 35	Oct. 4, 1910	1	18.89	7.53	1.66	8,034	14,461	8,762	15,772	[a].2
37	do	2	19.59	5.91	.91	8,163	14,694	8,720	15,695	.4
After 1 year:										
Box 35	Jan. 10, 1911	2	16.60	7.38	1.59	8,042	14,493	8,752	15,754	[a].1
38	do	2	12.68	4.54	.88	8,281	14,906	8,714	15,685	.4
After 1¼ years:										
Box 35	May 1, 1911	2	18.54	7.76	1.99	7,990	14,383	8,744	15,739	.0
39	do	2	14.97	4.48	.89	8,305	14,949	8,733	15,720	.4
After 1½ years:										
Box 35	July 10, 1911	2	14.02	8.11	2.13	7,932	14,277	8,718	15,693	.3
40	do	2	18.78	6.68	.97	8,106	14,590	8,736	15,724	.1
After 2 years:										
Box 35	Jan. 10, 1912	2	12.64	8.72	2.57	7,882	14,187	8,734	15,721	.1
41	do	2	19.31	5.20	.86	8,275	14,895	8,770	15,786	[a].3
After 2½ years:										
Box 35	July 8, 1912	2	13.69	8.50	2.73	7,872	14,169	8.706	15,671	.4
42	do	1	18.88	5.50	1.17	8,195	14,751	8,722	15,700	.4
After 3 years:										
Box 35	Feb. 1, 1913	2	17.85	7.88	2.38	7,895	14,210	8,661	15,589	.9
42	do	1	20.89	8.31	2.46	7,865	14,157	8,674	15,613	1.0
After 3¾ years:										
Box 43	Oct. 15, 1913	1	21.04	5.74	1.22	8,168	14,702	8,718	15,692	.2
44	do	2	10.00	7.20	1.24	8,011	14,420	8,692	15,645	.5

[a] Gain.

TABLE 13.—*Storage tests of New River, W. Va., coal exposed indoors at Key West (Dry Tortugas), Fla., in 350-pound portions.*[a]

	Date sampled.	Number of samples averaged.	Moisture.	Analysis on dry basis.				Heating value on "unit coal" basis.		
				Ash.	Sulphur.	Calories.	B. t. u.	Calories.	B. t. u.	Loss in B.t.u.
Run-of-mine coal:			*P. ct.*	*P. ct.*	*P. ct.*					*P. ct.*
As stored	Jan. 29, 1910	2	0.91	8.29	2.15	7,935	14,283	8,741	15,734	......
After 3 months	Apr. 26, 1910	2	1.19	11.18	3.11	7,642	13,756	8,733	15,720	0.1
6 months	July 14, 1910	1	1.26	10.27	3.54	7,697	13,855	8,712	15,682	.3
8 months	Oct. 4, 1910	2	1.14	11.67	5.45	7,539	13.570	8,731	15,715	.1
1 year	Jan. 10, 1911	1	1.83	10.79	4.30	7,628	13,730	8,710	15,678	.4
¼-inch crushed coal:										
As stored	Jan. 29, 1910	2	.75	7.15	2.33	8,068	14,523	8,777	15,799	......
After 3 months	Apr. 26, 1910	2	2.99	7.40	2.15	8,051	14,492	8,778	15,800	.0
6 months	July 14, 1910	1	1.50	7.40	1.74	7,984	14,371	8,694	15,649	1.0
8 months	Oct. 4, 1910	2	1.83	7.82	1.84	7,952	14,314	8,703	15,666	.8
1 year	Jan. 10, 1911	1	2.12	7.84	1.94	7,922	15,052	8,676	15,617	1.2

[a] These test portions were transferred at the end of 1 year from indoor storage to outdoor.

TABLE 14.—*Storage tests of New River, W. Va., coal exposed to weather at Key West (Dry Tortugas), Fla., in 350-pound portions.*

	Date sampled.	Number of samples averaged.	Moisture.	Analysis on dry basis.				Heating value on "unit coal" basis.		
				Ash.	Sulphur.	Calories.	B. t. u.	Calories.	B. t. u.	Loss in B.t.u.
Run-of-mine coal:			*P. ct.*	*P. ct.*	*P. ct.*					*P. ct.*
Lot A—As stored	Jan. 29, 1910	2	0.80	11.03	3.38	7,668	13,803	8,754	15,757	......
Lot B—As stored	......do........	2	.91	8.29	2.15	7,935	14,283	8,741	15,734	......
Lot A—										
After 3 months	Apr. 26, 1910	2	1.30	8.85	2.60	7,843	14,118	8,706	15,671	0.5
6 months	July 14, 1910	1	2.05	9.29	1.74	7,822	14,080	8,706	15,671	.5
8 months	Oct. 4, 1910	2	1.73	4.94	1.62	8,165	14,696	8,703	15,666	.6
1 year	Jan. 10, 1911	1	1.91	5.91	2.07	8,137	14,647	8,722	15,700	.4
Lot B—										
After 1¼ years	May 1, 1911	2	1.61	9.62	3.18	7,742	13,936	8,688	15,638	.6
1½ years	July 10, 1911	1	1.74	7.49	2.07	7,943	14,297	8,670	15,606	.8
2 years	Jan. 10, 1912	1	2.06	7.37	1.33	7,937	14,287	8,632	15,538	1.2
2½ years	July 8, 1912	1	1.08	7.20	1.64	7,916	14,249	8,598	15,476	1.6
3 years	Feb. 1, 1913	1	1.79	9.99	1.70	7,679	13,822	8,513	15,323	2.6
¼-inch crushed coal:										
Lot A—As stored	Jan 29, 1910	2	1.08	4.00	.73	8,362	15,052	8,745	15,740	......
Lot B—As stored	......do........	2	.75	7.15	2.33	8,068	14,523	8,777	15,799	......
Lot A—										
After 3 months	Apr. 26, 1910	2	2.28	5.57	1.11	8,189	14,741	8,721	15,698	.3
6 months	July 14, 1910	1	1.27	5.59	1.14	8,172	14,710	8,706	15,671	.4
8 months	Oct. 4, 1910	2	1.80	5.70	1.05	8,150	14,670	8,690	15,642	.6
1 year	Jan. 10, 1911	1	3.16	7.97	1.17	7,933	14,279	8,680	15,624	.7
Lot B—										
After 1¼ years	May 1, 1911	2	1.38	6.69	1.65	8,038	14,468	8,681	15,625	1.1
1½ years	July 10, 1911	1	1.33	6.58	1.83	7,983	14,369	8,618	15,512	1.8
2 years	Jan. 10, 1912	1	4.27	6.87	1.65	7,941	14,294	8,592	15,466	2.1
2½ years	July 8, 1912	1	1.19	6.71	1.90	7,907	14,233	8,547	15,385	2.6
3 years	Feb. 1, 1913	1	12.96	7.88	1.67	7,817	14,071	8,557	15,403	2.5

TABLE 15.—*General summary of tests of New River coal.*

Condition of test.	Percentage loss in heat value during—								
	3 months.	6 months.	9 months.	1 year.	1½ years.	2 years.	3 years.	4 years.	5 years.
Submerged:									
Portsmouth, N. H.	0.2	0.5	0.1	0.0	0.5	0.3	1.1	0.5	0.4
Norfolk, Va.	.3	.2	.1	.2	.2	.5	.9	.4	.5
Key West, Fla	.2	.3	.1	.2	.2	.0	.9	.4	....
Pittsburgh, Pa.—									
Run-of-mine coal	.1	.0	.0	.0	.1	.0	.6	.2	.1
¼-inch crushed coal	.0	.1	.0	.1	.1	.0	.7	.1	.1
Average	.16	.55	.06	.10	.55	.16	.84	.32	.28
Exposed indoors:									
Run-of-mine coal—									
Portsmouth, N. H.	.0	....	....	.1	.5	.3	.9	.8	1.0
Norfolk, Va.	.0	.1	.1	.2	.2	.2	.5	.7	.8
Key West, Fla	.1	.3	.1	.4	....	....	....	....	....
Pittsburgh, Pa	.1	.4	.0	.1	.4	.2	1.1	.9	.6
¼-inch crushed coal—									
Portsmouth, N. H.	.6	....	....	.4	.7	.9	1.3	1.6	1.4
Norfolk, Va.	.1	.4	.3	.2	.5	.4	1.0	1.2	1.2
Key West, Fla	.0	1.0	.8	1.2	....	....	....	....	....
Pittsburgh, Pa	.3	.5	.4	.6	.9	.6	1.6	1.6	1.7
Weathered:									
Run-of-mine coal—									
Portsmouth, N. H.	.2	.4	.4	.2	.4	.7	1.1	1.0	1.4
Norfolk, Va.	.0	.1	.0	.3	.2	.6	1.0	1.2	1.1
Key West, Fla	.5	.5	.6	.4	.8	1.2	2.6	....	....
Pittsburgh, Pa	.1	.6	.0	.4	.5	.7	1.3	1.0	1.2
¼-inch crushed coal—									
Portsmouth, N. H.	.3	.3	.3	.5	.7	.9	1.3	1.2	1.3
Norfolk, Va.	.1	.2	.3	.7	.7	1.2	1.5	1.8	1.3
Key West, Fla	.3	.4	.6	.7	1.8	2.1	2.5	....	....
Pittsburgh, Pa	.3	.7	.6	.6	.8	1.1	1.6	1.6	1.3

TABLE 16.—*Results of storage tests of New River coal showing ultimate composition of "unit" coal substance, and changes during storage.*

	Carbon.	Hydrogen.	Nitrogen.	Oxygen.	Total sulphur.	Sulphate sulphur.
Mine sample 1, Aug. 27, 1909	89.86	4.87	1.51	3.76	0.83	0.005
Mine sample 2, Dec. 14, 1909	89.70	4.89	1.66	3.75	2.18	....
Portsmouth, N. H.:						
As stored under water	89.52	4.89	1.52	4.07	1.06	.006
Submerged—						
2 years	89.71	4.68	1.74	3.87	1.04	.030
5 years	89.00	4.84	1.72	4.44	1.36	....
As stored, exposed outdoors	89.82	4.86	1.57	3.75	1.24	.004
Exposed outdoors—						
3 months	89.86	4.70	1.54	3.90	1.38	.020
6 months	90.11	4.91	1.63	3.35	1.29	.038
1 year	89.91	4.62	1.58	3.89	1.18	....
2 years	89.56	4.77	1.75	3.92	.98	.105
5 years	89.52	4.85	1.67	3.96	.78	....
Exposed indoors 5 years	89.42	4.78	1.71	4.09	1.05	....
Key West, Fla.:						
As stored under water	89.80	4.79	1.75	3.66	2.63	.011
Submerged—						
8 months	89.73	4.76	1.68	3.83	2.01	....
2 years	90.39	4.83	1.59	3.19	2.96	....
As stored, exposed outdoors	90.61	4.87	1.67	2.85	.79	.007
Exposed outdoors—						
8 months	89.68	4.70	1.62	4.00	1.29	....
2 years	88.13	4.87	1.83	5.17	2.07	.25
Pittsburgh, Pa.:						
As stored under water	89.99	5.00	1.59	3.42	.71	.006
Submerged—						
3 months	90.18	4.79	1.64	3.39	.73	.000
6 months	90.26	4.85	1.63	3.26	.77	.005
1 year	90.15	4.68	1.68	3.49	.75	....
As stored, exposed indoors.	89.59	4.86	1.55	4.00	1.25	.005
Exposed indoors—						
3 months	89.93	4.79	1.66	3.62	1.23	.020
6 months	89.36	5.17	1.65	3.82	1.38	.022
1 year	90.08	4.67	1.63	3.62	1.26	....
2 years	90.31	4.74	1.70	3.25	1.10	.043
Exposed outdoors, 5 years.	90.23	4.75	1.74	3.28	.76	.08

DISCUSSION OF RESULTS OF TESTS.

The tables show that the maximum deterioration in heating value in one year was 1.2 per cent in one-fourth inch coal exposed indoors at Key West (Dry Tortugas); and the maximum in two years was 2.1 per cent in the same portion after a second year out of doors. The warmer climates of Norfolk and Key West (Dry Tortugas) caused uniformly greater deterioration in the exposed coal than the cooler ones of Pittsburgh and Portsmouth. The one-fourth inch coal showed losses almost always 50 to 100 per cent greater than those of the run-of-mine.

After one year the submerged coal in six out of eight portions at the different storage points showed no loss of heat value. Two portions had lost about 0.4 per cent. After two years' submergence, three out of eight portions showed losses ranging from 0.4 to 0.6 per cent, the remainder being less than 0.2 per cent, and after five years the loss in two portions was practically nothing, the other two tested showing losses of 0.4 and 0.5 per cent.

Slight, continuous decreases in heating value were noted after the two-year period in the exposed coal, the maximum being 2.6 per cent at Key West (Dry Tortugas). In five years the maximum loss at Portsmouth was 1.4 per cent, at Pittsburgh 1.7 per cent, and at Norfolk 1.3 per cent.

It should be noted that the probable experimental accuracy in the determination of calorific value by the method used was not more than 0.2 per cent, and that, including the effect of the errors in determination of moisture, ash, and sulphur, in computing the "unit coal" value, a possible deviation of 0.4 per cent might occur between the values obtained for duplicate samples of the same portion. The losses indicated, therefore, in the submergence tests are almost within the experimental error, and may be said to have been inconsiderable. The tests of coal in box 10 at Norfolk appear to show that alternate drying in the open air for brief intervals between the submergence periods causes some loss, although not a material one.

The variation in ultimate composition of the coal substance as shown in Table 16 was very slight, if any. The probable experimental error in these analyses is 0.25 per cent for carbon, 0.03 per cent for hydrogen, 0.02 per cent for nitrogen, and 0.20 per cent for moisture and ash, throwing an aggregate probable error on the oxygen (determined by difference) of 0.50 per cent, or a possible variation between duplicates of 1 per cent. Any indications of change in percentage of oxygen in the coal during storage are, therefore, within the experimental error, and the only conclusion justifiable is that the change in oxygen content, if any, appears to be of the same order of magnitude as the change in calorific value.

No actual determination of the amount of physical deterioration of lumps was made, but by observation of the run-of-mine coal stored outdoors at Pittsburgh it was noted that very little slacking or weakening of the lumps occurred during two years. This is illustrated in Plate IV, *A*, which shows the condition of the run-of-mine coal after two years' exposure. Plate IV, *B*, shows crushed coal after two years' exposure under similar conditions.

CONCLUSION.

In general, the conclusion to be drawn from these tests is that New River coal, under severe conditions of outdoor exposure to the weather, deteriorates in heating value approximately 1 per cent in the first year, 2 per cent in the first two years, and not over 3 per cent in five years. Storage under water prevents practically all deterioration during one year, and no more than 0.5 per cent has been found in any test for two years or less. Salt water possesses no advantage over fresh water in preventing deterioration. Intermittent exposure and partial drying of the submerged coal probably causes deterioration in some degree, although very small.

Submergence storage of New River coal is not to be recommended for the sake of preventing deterioration in heat value. Its advantage lies only in insuring against spontaneous combustion.

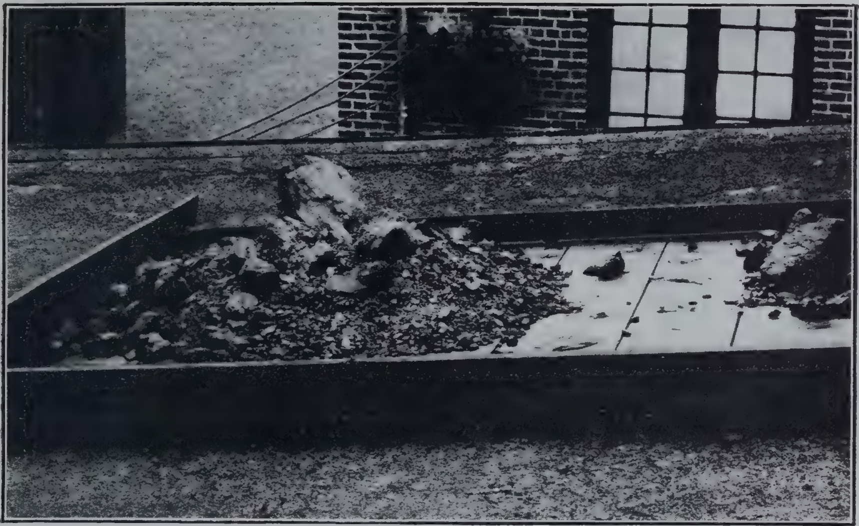
TESTS OF PITTSBURGH GAS COAL AT ANN ARBOR, MICH.

Experiments to determine the loss in heating value of coal of the Pittsburgh bed and its deterioration for purposes of illuminating-gas manufacture, during periods of storage ranging from six months to five years, were begun in November, 1910, at Ann Arbor, Mich., in cooperation with the Michigan Gas Association and the University of Michigan. The periodic sampling of the coal for determination of its heating value was done under the direction of Prof. A. H. White, of the university, who also carried out the tests of the coal for yields of gas and by-products. The results of the gas tests are to be reported by Prof. White.

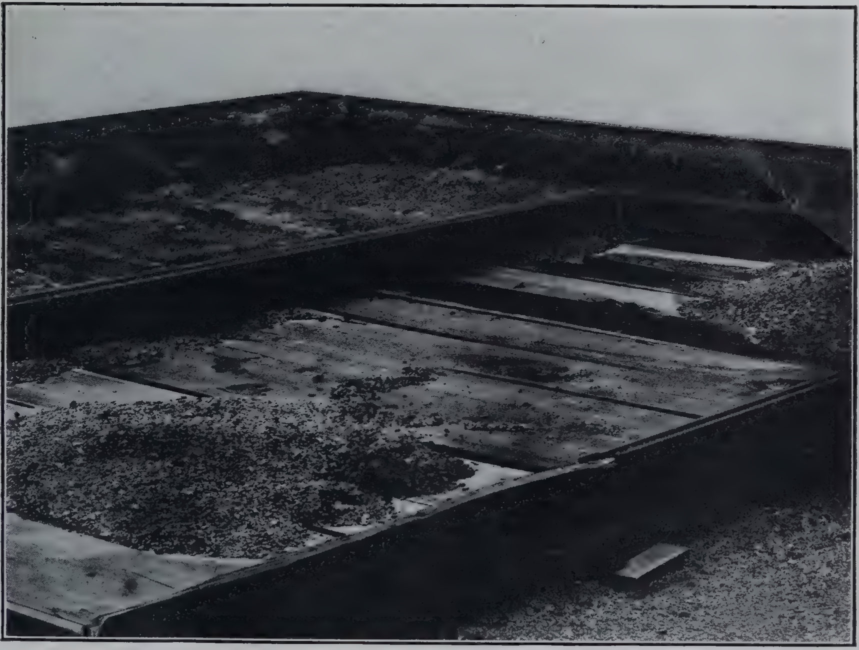
Coal was obtained for the tests from two different mines, both working the Pittsburgh bed and producing coal commonly used in gas manufacture.

SOURCE OF THE COAL.

The coal designated in the tests "AA15" was mined November 1, 1910, at the Schoenberger mine at Baird Station, Washington County, Pa. It consisted of a small carload (21½ tons, net weight) of lump coal screened over a three-fourths-inch bar screen, and was loaded and sampled under the supervision of one of the mining engineers of the bureau. Mine samples were taken at six different points in the mine and a



A. RUN-OF-MINE NEW RIVER COAL AFTER TWO YEARS' WEATHERING AT PITTSBURGH, PA. (SHOWING LUMPS INTACT).



B. FINELY CRUSHED NEW RIVER COAL AFTER TWO YEARS' WEATHERING AT PITTSBURGH, PA.

composite of these made for analysis. The car arrived at Ann Arbor November 12, 1910, and was unloaded into the bins November 15 and 16, a gross sample of 3 to 4 tons representing the car being set aside at that time. On November 18 and 19 this gross sample was reduced to two 300-pound lots as described in page 24, and on November 23 these were further reduced for analysis to two laboratory samples of 2½ to 3 pounds each.

The coal designated "AA16" was mined December 9, 1910, at Consolidation No. 63 mine at Monongah, Marion County, W. Va. It was a small carload (29½ tons, net weight) of coal screened over a three-fourths-inch bar screen, loaded and sampled under the supervision of a mining engineer of the bureau. Mine samples were taken at four different points in the mine and a composite of these made for analysis. The car arrived at Ann Arbor December 28, 1910, and was unloaded into the bins December 30 and 31. A gross sample of 3 or 4 tons was removed during the unloading and reduced at that time, as described elsewhere (p. 24), to two 300-pound lots. On January 6, 1911, these were crushed and reduced further to laboratory samples.

TESTS IN OPEN BINS.

The bins were located at the works of the Ann Arbor Gas Co. in the open yard adjoining the retort house. The coal in the bins was exposed to the weather, the bins being so constructed that the conditions in an ordinary coal pile 10 feet deep were approximately simulated. Each of the two bins covered a floor space 11½ by 7½ feet, was 10 feet high, and was divided by board partitions into six compartments. Each compartment was 7½ feet long, 10 feet high, and 20 inches wide, held about 3 tons of coal at 7 feet depth and 4 tons at 9½ feet depth. The bins were backed up against a concrete wall, had a board floor, and were uncovered except for a screen of poultry netting.

At the end of each successive period one of the six compartments was emptied and the coal tested, both for heating value and for gas-making qualities.

TESTS OF STORAGE BY SUBMERGENCE UNDER WATER.

Four barrels, each holding 300 to 320 pounds, were filled, two with each kind of coal. Both ends of each barrel were perforated with about 10 ¾-inch holes to allow escape of air and complete filling with water when submerged.

The barrels of coal "AA15," numbered 1 and 2, were filled with coal (part of the 3 or 4 ton gross sample above referred to) on January 7, 1911, and were submerged January 14, 1911; those of coal "AA16," numbered 3 and 4, were filled January 9 and submerged January 14.

The barrels were lowered under the water of a supply basin (see Pl. V, *A*, p. 32) 6 or 8 feet deep, near the gas works, the water of of which is kept fresh constantly by springs and does not freeze.

One of the barrels of each kind of coal remained submerged continuously until the expiration of 5½ years of storage. The other was raised after the expiration of 6 months, 1½ years, 2½ years, 3½ years, and 4½ years, sampled each time, and returned to the water.

METHODS OF PREPARING AND SAMPLING COAL.

The cars of coal were unloaded by hand, single shovelfuls being thrown in rotation into each of the six bins and into a chute leading to an inclosed sampling floor. The carload was thus divided into seven equal representative portions. The portion on the sampling floor, 3 or 4 tons, was, without further preparation, divided into four equal portions, three of these being sacked for gas tests, and the fourth reserved for sampling. By alternate shovelfuls this last quarter was divided into two duplicate portions of 800 to 1,000 pounds each, and these in turn were each divided into five equal portions. Of these five portions, of 160 to 200 pounds each, one served for a special "change of weight" test in an open ash-can, two of the others made up the barreled lot for submergence, and the last two portions, aggregating 300 to 400 pounds, served for reducing down to laboratory samples. This was done by crushing the coal and quartering it in the usual manner by spreading out and rejecting opposite quarters. After each reduction of quantity the coal was crushed to a smaller size.

TESTS TO DETERMINE CHANGE IN WEIGHT DURING STORAGE.

In order to determine the change in weight of the dry coal substance by oxidation or other weathering effect, during storage, two weighed portions of each coal of about 200 pounds each were placed in galvanized-iron ash cans, without covers, and exposed to outdoor conditions. The bottoms of these cans were perforated to allow water to drain out, the coal resting on two thicknesses of 16-mesh wire screening so as to reduce mechanical losses to a minimum. Similar screening covered the tops of the cans. After standing indoors for two or three weeks, to become air-dried, the cans were weighed and then buried to half their depth in the coal of the test bins. After stated periods of exposure the cans were air dried, weighed, sampled, again weighed, and returned to the bins. By computing from the analysis and weight the dry coal substance present, any change of weight due to weathering was determined. The weighings were made with an accuracy of 0.5 pound or about 0.2 per cent.

The results of these tests indicate little, if any, change of weight within the error of measurement of the dry coal substance in five years' exposure. Table 17 shows the actual weights.

TABLE 17.—*Change in weight of Pittsburgh gas coal during five years' exposure.*

Item.	Coal AA15, from Baird Station, Pa. (can 2).		Coal AA16, from Monongah, W. Va. (can 4).	
	As stored.	After five years.	As stored.	After five years.
Gross weight, pounds	239.0	238.5	237.5	235.0
Weight of can, pounds	30.5	30.5	30.0	30.0
Net weight of coal, pounds	208.5	208.0	207.5	205.5
Moisture in coal, per cent	2.2	1.6	2.9	1.7
Weight of dry coal, pounds	203.9	204.7	201.5	202.0
Change in dry weight, per cent	....	+0.4	....	+0.3

The recorded weights of cans 1 and 3, taken at intervals during the five years' period, are incomplete and have been omitted from the table, because, unfortunately, a record was not preserved in every instance of the weights both before and after sampling so as to show how much coal was lost in sampling. The final change in weight of these portions therefore represents both the loss in sampling and the change due to weathering, and the latter is indeterminate.

The results showing deterioration in heating value of the two coals, both in the open bins and in the submergence tests, are given in Tables 18 and 19. It is to be noted, as was explained in connection with the tests of New River coal, that the only fair basis for comparing analyses in determining deterioration is the dry coal substance, free of sulphur and ash.

On this basis the amount of deterioration in one year's open air storage was practically negligible, even in the upper six inches of the exposed coal. During the second, third, fourth, and fifth years the deterioration proceeded very slowly and did not reach an amount greater than 1.1 per cent in five years. The submerged portions may be said to have suffered practically no loss measureable by the degree of accuracy used.

TABLE 18.—*Storage tests of screened lump (over ¾-inch) coal from the Pittsburgh bed at Baird Station, Pa., exposed to weather at Ann Arbor, Mich., in 3-ton lots.*

Weight under test.	Method of storing.	Sample from—	Date of sampling.	Duration of storage.	Number of samples averaged.	Moisture.	Analysis on dry basis.						Heating value of "unit coal."		
							Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Calories.	B. t. u.	Calories.	B. t. u.	Loss in B. t. u.
						Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*					*Per ct.*
		Mine	Nov. 3, 1910	....	....	3.94	34.93	59.14	5.93	1.08	7,991	14,384	8,545	15,381	....
		Car during loading.	Nov. 1, 1910	....	4	2.44	....	....	6.30	.87	7,968	14,343	8,549	15,388	....
		Car during unloading.	Nov. 23, 1910	....	2	2.23	....	....	6.34	.89	7,959	14,325	8,541	15,374	....
3 tons	Open bin	Entire bin	June 8, 1911	6 months	2	2.41	....	....	8.29	.90	7,782	14,008	8,539	15,370	0.0
Do	do	Surface of bin	do	do	1	2.00	....	....	7.13	.95	7,895	14,211	8,551	15,392	a.1
Do	do	Entire bin	Dec. 4, 1911	1 year	2	6.34	....	....	8.47	.96	7,752	13,954	8,526	15,347	.2
Do	do	Surface of bin	do	do	1	8.59	....	....	8.16	1.05	7,782	14,008	8,528	15,350	.2
Do	do	Entire bin	Dec. 19, 1912	2 years	2	2.38	34.27	58.14	7.60	1.07	7,777	13,998	8,471	15,248	.8
Do	do	Surface of bin	do	do	1	2.13	34.09	58.73	7.18	1.07	7,817	14,071	8,474	15,253	.8
Do	do	Entire bin	Nov. 3, 1913	3 years	2	3.80	34.55	57.22	8.24	1.02	7,727	13,908	8,477	15,259	.7
Do	do	Surface of bin	Oct. 31, 1913	do	1	2.63	36.85	54.51	8.64	.75	7,716	13,889	8,497	15,295	.5
Do	do	Entire bin	Dec. 11, 1914	4 years	1	2.72	35.84	57.90	6.26	1.03	7,916	14,249	8,493	15,287	.6
Do	do	Surface of bin	do	do	1	2.45	35.49	57.60	6.91	1.08	7,857	14,143	8,492	15,286	.6
Do	do	Entire bin	Jan. 29, 1916	5 years	1	1.88	35.36	58.09	6.55	1.12	7,876	14,177	8,479	15,262	.7
Do	do	Surface of bin	do	do	1	1.55	35.46	58.27	6.27	1.01	7,902	14,224	8,477	15,259	.7
300 pounds	Submerged	Barrel 1	Jan. 7, 1911	As stored	2	2.09	....	....	5.82	.82	7,998	14,396	8,533	15,359	....
Do	do	do	June 15, 1911	6 months	1	1.21	....	....	5.84	.97	8,015	14,427	8,557	15,403	a.3
Do	do	do	May 29, 1912	1½ years	2	4.42	35.23	58.09	6.69	1.13	7,885	14,192	8,501	15,302	.4
Do	do	do	June 9, 1913	2½ years	1	6.04	35.74	57.01	7.25	1.29	7,828	14,090	8,499	15,298	.4
Do	do	do	June 8, 1914	3½ years	1	3.72	36.64	56.97	6.39	1.12	7,947	14,305	8,540	15,372	a.1
Do	do	do	May 19, 1915	4½ years	1	2.47	35.12	55.95	8.93	1.06	7,740	13,932	8,559	15,406	a.3
Do	do	Barrel 2	do	do	1	2.47	36.31	57.17	6.52	1.31	7,919	14,254	8,527	15,349	.1

a Gain.

TABLE 19.—*Storage tests of screened lump (over ¾-inch) coal from the Pittsburgh bed at Monongah, W. Va., exposed to the weather at Ann Arbor, Mich.; in 4-ton lots.*

Weight under test.	Method of storing.	Sample from—	Date of sampling.	Duration of storage.	Number of samples averaged.	Moisture.	Analysis on dry basis.						Heating value of "unit coal."		
							Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Calories.	B. t. u.	Calories.	B. t. u.	Loss in B. t. u.
						Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*					*Per ct.*
		Mine	Dec. 10, 1910	....	....	2.95	36.07	58.16	5.77	0.69	7,935	14,283	8,458	15,224	....
		Car during loading	do	....	4	2.35	....	....	7.78	.68	7,806	14,050	8,509	15,316	....
		Car during unloading.	Jan. 6, 1911	....	2	2.91	....	....	9.04	.68	7,681	13,827	8,514	15,325	....
4 tons	Open bin	Entire bin	June 8, 1911	6 months	2	2.22	....	....	8.85	.74	7,726	13,907	8,528	15,350	*a* 0.2
Do	do	Surface of bin	do	do	1	2.16	....	....	8.90	.56	7,711	13,880	8,513	15,323	.0
Do	do	Entire bin	Dec. 16, 1911	1 year	2	3.19	....	....	9.24	.78	7,680	13,823	8,516	15,329	.0
Do	do	Surface of bin	do	do	1	4.56	....	....	9.19	.82	7,674	13,814	8,507	15,313	.1
Do	do	Entire bin	Dec. 19, 1912	2 years	2	2.40	35.77	54.56	9.68	.88	7,593	13,667	8,465	15,237	.6
Do	do	Surface of bin	do	do	1	2.81	36.33	55.88	7.79	.77	7,742	13,936	8,443	15,197	.8
Do	do	Entire bin	Nov. 3, 1913	3 years	2	3.45	36.58	55.72	7.70	.72	7,770	13,986	8,464	15,235	.6
Do	do	Surface of bin	do	do	1	2.46	35.04	56.80	8.16	1.12	7,763	13,973	8,511	15,320	.0
Do	do	Entire bin	Dec. 11, 1914	4 years	1	2.41	36.85	55.61	7.54	.81	7,785	14,013	8,467	15,241	.5
Do	do	Surface of bin	do	do	1	3.26	37.28	55.80	6.92	.70	7,841	14,114	8,466	15,239	.6
Do	do	Entire bin	Jan. 29, 1916	5 years	1	1.93	37.06	55.83	7.11	.75	7,812	14,062	8,455	15,219	.7
Do	do	Surface of bin	do	do	1	1.73	37.47	54.88	7.65	.63	7,732	13,918	8,416	15,149	1.1
300 pounds	Submerged	Barrel 3	Jan. 9, 1911	As stored	2	2.81	....	....	9.10	.72	7,666	13,799	8,506	15,311	....
Do	do	do	June 15, 1911	6 months	1	1.41	....	....	8.23	.69	7,776	13,996	8,521	15,338	*a* .2
Do	do	do	May 29, 1912	1½ years	1	3.00	36.54	55.74	7.72	.75	7,754	13,957	8,453	15,215	.6
Do	do	do	June 9, 1913	2½ years	1	4.75	37.89	54.75	7.36	.87	7,810	14,058	8,479	15,262	.3
Do	do	do	June 8, 1914	3½ years	1	3.25	37.33	52.83	9.84	.98	7,630	13,734	8,524	15,343	*a* .2
Do	do	do	May 19, 1915	4½ years	1	2.16	38.01	52.75	9.24	.83	7,683	13,829	8,521	15,338	*a* .2
		Barrel 4	do	do	1	2.69	37.71	53.63	8.66	.81	7,692	13,846	8,474	15,253	.4

a Gain.

Table 20.—*Ultimate composition of coals from the Pittsburgh bed, on basis of ash and moisture free substance, after various periods of storage at Ann Arbor, Mich.*

	"AA15" coal from Baird, Pa.					"AA16" coal from Monongah, W. Va.				
	Carbon.	Hydrogen.	Nitrogen.	Oxygen.	Sulphur.	Carbon.	Hydrogen.	Nitrogen.	Oxygen.	Sulphur.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Mine sample (composite)	85.44	5.41	1.52	6.48	1.15	85.17	5.47	1.51	7.12	0.73
Car sample, as unloaded	85.09	5.32	1.65	6.79	1.15	84.84	5.67	1.68	6.88	.93
Coal in open bins after 4 years' weathering	84.91	5.47	1.61	6.91	1.10	85.01	5.62	1.74	6.75	.88
Coal in open bins after 5 years' weathering	85.27	5.56	1.70	6.27	1.20	84.86	5.61	1.68	7.04	.81
Same, 6-inch surface layer	84.94	5.46	1.71	6.81	1.08	84.95	5.74	1.75	6.88	.68
Coal, as submerged for test	85.35	5.54	1.68	6.41	1.02	84.35	5.49	1.63	7.57	.96
Same after 4½ years' storage, submerged	85.61	5.64	1.66	5.69	1.40	84.84	5.68	1.73	6.86	.89

TESTS OF POCAHONTAS COAL MADE ON THE ISTHMUS OF PANAMA.

During the year ended June 1, 1910, a large number of samples were taken of Pocahontas (Va.) coal as unloaded on one part of the general stock pile of the Panama Railroad Co. at dock No. 14, Cristobal, Isthmus of Panama. These samples were analyzed in order to determine the average heating value of the coal, as placed on the pile, for comparison with the heating value of the same coal as determined on removal from the pile after different periods of storage. Some time previous to June 1, 1910, when the fact was discovered by the Bureau of Mines, this part of the stock pile was several times almost entirely dug up and consumed, and no samples of the coal were taken. The analyses made up to that time became, therefore, useless for any test of deterioration, and a new series of tests was begun.

On June 16, 1910, a small test pile of 120 tons of Pocahontas run-of-mine was established near dock No. 14, separate from the general stock pile. The coal was the cargo of the steamship *Vauxhall*, leaving Norfolk, Va., June 1, and unloaded at Cristobal June 13 to 18. One average sample of the coal as placed on the pile was sent to the bureau for analysis, but no report was made to the bureau of the exact method of taking the sample. Every three months after the test pile was established a 10-ton portion (consisting of an entire vertical section across the shorter dimension of the pile) was removed and thoroughly sampled. Eight samples were taken each time, by throwing aside 400 to 800 pounds into each of four boxes, in small portions at regular intervals as the 10 tons were removed; these 400-pound portions were then crushed and reduced by quartering, two small can samples being taken from each.

A summary of the results follows:

TABLE 21.—*Storage test of Pocahontas (Va.) coal.*

[120 tons in open pile, near dock No. 14, Cristobal, Isthmus of Panama.]

Item.	Original as stored, June 16, 1910 (sample).	After 3 months' storage, Sept. 21, 1910 (average of 7 samples).	After 6 months' storage, Dec. 18, 1910 (average of 8 samples).	After 9 months' storage, Mar. 20, 1911 (average of 8 samples).	After 13 months' storage, July 18, 1911 (average of 8 samples).	After 2 years' storage, June 15, 1912 (average of 2 samples).
Air-drying loss	....	4.37	6.28	3.89	4.21	5.55
Coal, as received:						
Moisture	0.94	4.96	6.72	4.47	5.34	6.79
Ash	5.51	6.76	6.66	5.53	6.20	6.56
Sulphur	.73	.49	.52	.59	.48	.57
Calories	8,188	7,721	7,625	7,764	7,716	7,508
British thermal units	14,738	13,898	13,725	13,975	13,889	13,515
Coal, free of moisture, sulphur and ash (calculated):						
Calories	[a] 8,794	8,786	8,761	8,766	8,762	8,723
British thermal units	15,829	15,815	15,770	15,779	15,772	15,701
Percentage of loss (in B. t. u.) during storage	....	0.09	0.38	0.32	0.37	0.81

[a] For a check on this analysis of coal as stored, the analyses of 14 samples taken from the same cargo when loaded at Norfolk, June 1, 1910, show on the moisture, sulphur, and ash-free basis an average calorific value of 8,790 calories.

As explained under the report on New River coal, the only fair basis of comparison in studying deterioration of heating value is the coal substance free of its accidental impurities—moisture, sulphur, and ash.

On this basis, therefore, and on the basis of average samples of the entire cross-section of the pile, the results given in Table 21 show that during one year's outdoor exposure this coal deteriorated very slightly (less than 0.4 per cent) in heating value, and that the deterioration took place entirely during the first six months (June 15 to Dec. 15). There was a further deterioration of 0.4 per cent during the second year.

The climatic conditions during the period of storage are indicated by the following table:

TABLE 22.—*Monthly temperature averages and precipitation at Colon, R. P., June 1, 1910, to June 1, 1912.*

	Temperature of air.			Average temperature of sea water.	Total precipitation.
	Average mean.	Average maximum.	Highest.		
1910.	*° F.*	*° F.*	*° F.*	*° F.*	*Inches.*
June	79.4	83.9	89	83.1	13.63
July	77.6	82.1	86	82.5	21.07
August	78.4	82.5	86	83.2	14.93
September	78.6	84.0	88	83.6	12.05
October	78.5	84.4	89	82.5	15.65
November	77.8	82.1	88	80.6	30.04
December	77.3	80.5	82	79.8	15.20
1911.					
January	78.4	81.4	82	80.2	0.99
February	77.9	81.1	82	80.3	1.81
March	78.3	81.5	82	80.3	1.41

TABLE 22.—*Monthly temperature averages and precipitation at Colon, R. P., June 1, 1910, to June 1, 1912*—Continued.

	Temperature of air.			Average temperature of sea water.	Total precipitation.
	Average mean.	Average maximum.	Highest.		
1911.	*° F.*	*° F.*	*° F.*	*° F.*	*Inches.*
April	79.6	82.8	84	81.6	3.06
May	79.5	84.8	88	82.6	17.13
June	79.3	83.7	88	82.4	16.58
July	81.1	84.4	86	84.0	14.58
August	79.7	83.6	86	84.1	11.60
September	80.6	84.7	90	84.8	11.62
October	79.4	83.6	90	81.6	16.53
November	79.4	84.3	89	81.9	15.81
December	82.0	86.4	89	81.7	2.63
1912.					
January	82.1	86.4	88	80.9	0.28
February	80.8	84.7	88	80.7	1.81
March	82.5	86.8	88	81.1	0.66
April	82.8	87.7	90	82.8	0.75
May	82.0	86.6	91	83.4	12.03

TESTS OF SHERIDAN (WYO.) SUBBITUMINOUS COAL.

About December 30, 1907, five wooden bins, constructed by the Chicago, Burlington & Quincy Railway Co. in the railroad yards at Sheridan, Wyo., were filled with coal from the Dietz mines near Sheridan. The bins adjoined one another in the same structure, the side walls of each serving as partitions. They were built of heavy matched lumber, but allowed more or less circulation of air through cracks. One bin was left without roof, and the coal thus fully exposed to the weather, but the other four were roofed over.

Bin 1, 4 feet wide, 8 feet high, with open top and end, contained about 4 tons of run-of-mine coal piled about 5 feet deep.

Bin 2 was a duplicate of bin 1, except that top and ends were closed.

Bin 3, of the same size as bins 1 and 2, with closed top and ends, contained about 4 tons of run-of-mine coal, moistened with about 7 per cent of added water.

Bin 4, 4 feet wide, 18 feet high, with closed top and ends, contained 10 to 12 tons of run-of-mine coal, piled about 15 feet deep.

Bin 5 was a duplicate of bin 4, except that slack coal (through 3-inch mesh screens) was used instead of run of mine.

Bins 1, 2, 3, and 4 were loaded with run-of-mine coal from one carload, and three samples were taken from the car as it was unloaded. Small portions were thrown aside at regular intervals during the unloading, and the three gross samples thus obtained were crushed to one-half-inch size and quartered down. Bin 5 was filled from a car of the commercial output of slack coal (3-inch screenings), and one sample was taken by the method just described.

All sampling after that at the start of the tests and prior to that at the expiration of two and three-fourths years was done by the so-called "grab" method, so as not to disturb the entire lot, and thus expose its under portions to undue weathering. A spot 2 by 3 feet square was dug away for about 1 foot in depth and several small, well-distributed portions removed therefrom. These were combined, crushed, mixed, and quartered to the laboratory size.

The sampling carried out October 1, 1910, after a two and three-fourths years' period, was done by rehandling the entire amount in each bin. The coal was transferred to a temporary bin, and during the transfer an average sample was taken by the method used when loading the bins. The coal was then returned to its proper bin.

The samples were mailed to the Pittsburgh laboratory in sealed metal cans and there analyzed. The "unit coal" basis, as previously explained (p. 12), was used in all comparisons of calorific values.

It was impracticable in these tests to determine accurately the change in weight of the actual fuel substance of the coal, and in fact an element of uncertainty due to the same cause enters into practically all tests of deterioration of the coal. Laboratory experiments have shown that coal ordinarily increases slightly in weight on exposure to the air, if the measurement be made on the basis of actual fuel substance. It is possible, therefore, that the net losses in heating value may be slightly less than are reported, since the actual weight of fuel substance present may be somewhat greater, although its heat value is less than when the coal was stored.

TABLE 23.—*Loss in heat value of Sheridan (Wyo.) coal during storage.*

	As received.					"Unit coal" basis.		Loss in B. t. u.
	Moisture.	Ash.	Sulphur.	Calories.	B. t. u.	Calories.	B. t. u.	
Bin 1—open:	*Per cent.*	*Per cent.*	*Per cent.*					*Per cent.*
As stored	21.38	7.77	1.11	5,181	9,326	7,370	13,266	....
After 3 months	21.06	9.83	1.05	4,915	8,847	7,174	12,913	2.66
After 9 months	20.39	8.62	.88	4,982	8,968	7,070	12,726	4.07
After 2¾ years	18.75	7.24	.76	5,250	9,450	7,135	12,843	3.19
Bin 2—closed:								
As stored	21.38	7.77	1.11	5,181	9,326	7,370	13,266	....
After 3 months	20.93	10.36	.81	4,907	8,833	7,202	12,964	2.28
After 9 months	17.57	10.00	1.08	5,034	9,061	7,010	12,618	4.88
After 2¾ years	15.32	7.96	.85	5,420	8,756	7,094	12,769	3.75
Bin 3—closed, coal moistened:								
As stored	21.38	7.77	1.11	5,181	9,326	7,370	13,236	....
After 3 months	22.00	9.59	1.00	4,821	8,678	7,109	12,796	3.54
After 9 months	18.86	7.90	1.01	5,129	9,232	7,053	12,695	4.30
After 2¾ years	15.62	9.70	.90	5,244	9,439	7,076	12,737	3.99
Bin 4—deep, closed:								
As stored	21.38	7.77	1.11	5,181	9,326	7,370	13,236	....
After 3 months	20.38	9.00	.91	5,116	9,209	7,303	13,145	.91
After 9 months	18.78	6.56	.80	5,221	9,384	7,033	12,659	4.57
After 2¾ years	12.53	9.84	.94	5,381	9,686	6,982	12,568	5.26
Bin 5—closed, deep, screenings:								
As stored	20.82	11.62	1.21	4,915	8,847	7,355	13,199	....
After 3 months	20.65	10.63	.88	4,582	8,788	7,166	12,899	2.57
After 9 months	18.21	10.87	.94	4,974	8,953	7,066	12,719	3.93
After 2¾ years	16.20	11.99	.92	4,975	8,955	6,990	12,582	4.96

Three mine samples were taken from the Dietz mines at different times, one from No. 2 mine, April 9, 1909, one from No. 4 mine, November 22, 1911, and one from No. 2 mine, November 22, 1911. The analyses of these three mine samples are given below for comparison with those of the car samples taken when the coal was stored. These samples represent the average commercial output of the mines. The interval of two and one-third years between these samples gives a check on the uniformity of the sampling and analytical methods.

TABLE 24.—*Analyses of samples of coal from Dietz mines, Sheridan, Wyo.*

Mine from which sample was taken.	As received.					"Unit coal" basis.[a]	
	Moisture.	Ash.	Sulphur.	Calories.	B. t. u.	Calories.	B. t. u.
	Per cent.	*Per cent.*	*Per cent.*				
No. 2	23.55	4.98	0.74	5,232	9,418	7,367	13,261
No. 2	21.64	8.99	1.28	5,058	9,104	7,358	13,244
No. 4	22.85	8.46	1.18	4,985	8,973	7,219	13,174

[a] Moisture, sulphur, and ash-free basis.

After nine months (Sept. 1, 1908), a photograph was taken of bins 1 and 2, showing the effect of the closed bin as compared with the open in preventing slacking of lumps. (See Pl. V, *B*.) After two and three-fourths years (September, 1910) the coal in each bin was photographed at rather close range, before and after removal from the bins, so as to show its physical appearance both on the surface and after being thoroughly mixed by rehandling. (See Pls. V, *C*, VI, and VII.) Careful observations also were made at this time to determine the extent of the slacking in each bin.

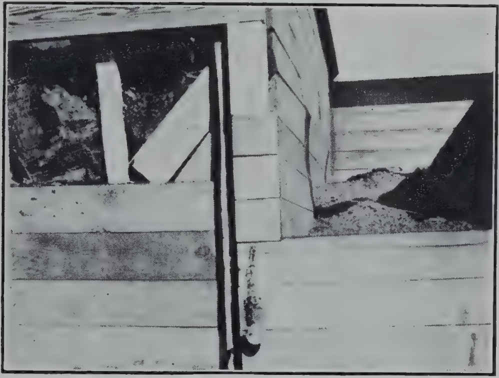
Bin 1 (open, coal piled 5 feet deep): A fairly uniform layer, 8 inches to 12 inches thick, of closely packed, finely disintegrated coal (see Pl. VI, *A*) had formed over the surface. Below that the coal was practically in the same condition as when stored. Near the center, especially, the lumps were harder and brighter than at the sides, and harder also than those in bins 2, 3, and 4. (See Pl. VII.)

Bin 2 (closed, coal piled 6 feet deep): Coal had slacked somewhat on the surface (Pl. VI, *B*), but had not completely disintegrated, as had coal in bin 1. The lumps all through the bin were of a dull color and showed more or less cracking. (See Pl. VII, *B*.) They broke up badly on handling.

Bin 3 (closed, 6 feet deep, coal moistened): Lumps had cracked and weakened more than in bin 2; otherwise appearance was nearly the same.

Bin 4 (closed, run-of-mine coal, 15 feet deep): Physical appearance of coal in the upper two-thirds of bin was much the same as in bin 2, that is, the lumps were still more or less intact, but were cracked and weakened so that they broke up badly on handling. The coal in the lower third of the pile seemed to be somewhat brighter and firmer.

A. METHOD OF SUBMERGING BARRELS OF PITTSBURGH COAL AT ANN ARBOR, MICH.

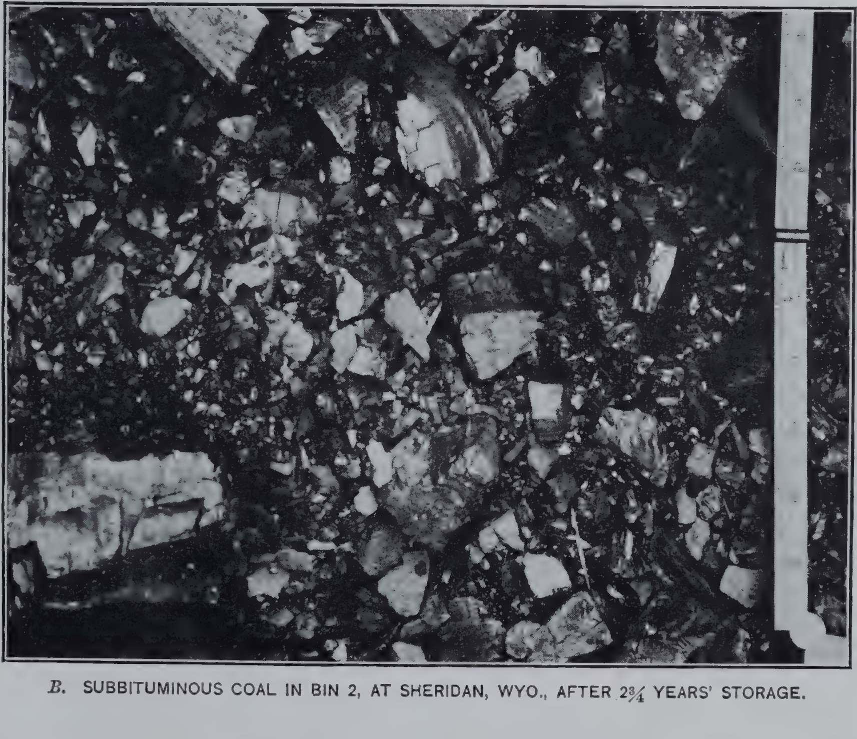


B. SUBBITUMINOUS COAL STORED AT SHERIDAN, WYO., AFTER 2¾ YEARS.

Bin 1 on right, bin 2 on left. Note effect of closed bin on preserving lumps.

C. SUBBITUMINOUS COAL FROM BIN 1, AFTER 2¾ YEARS' STORAGE AT SHERIDAN, WYO.

A. SUBBITUMINOUS COAL IN BIN 1, AT SHERIDAN, WYO., AFTER 2¾ YEARS' STORAGE.



B. SUBBITUMINOUS COAL IN BIN 2, AT SHERIDAN, WYO., AFTER 2¾ YEARS' STORAGE.

A. NEAR VIEW OF COAL FROM BIN 1, AFTER REMOVAL. NOTE SIZE OF LUMPS. (SHERIDAN, WYO.)

B. NEAR VIEW OF COAL FROM BIN 2, AFTER REMOVAL. NOTE SIZE OF LUMPS. (SHERIDAN, WYO.)

Bin 5 (closed, screenings, 15 feet deep): Coal apparently was less weathered than in bin 4; seemed to have been very little altered in lower two-thirds of pile.

Referring to the results in Table 23, during the first three months, the greatest loss, 3.54 per cent, was in the shallow bin, bin 3, where the coal had been moistened. Then followed, in order, bin 1, 2.66 per cent; bin 5, 2.57 per cent; bin 2, 2.28 per cent; and bin 4, 0.91 per cent. The added moisture seemed to increase the deterioration. After nine months, however, the order was changed, bin 2, the closed, shallow bin, showing the greatest loss, 4.88 per cent; and following that, in order, bin 4, 4.57 per cent; bin 3, 4.30 per cent; bin 1, 4.07 per cent; bin 5, 3.93 per cent. During the hot, dry weather of summer, the deterioration had been more or less equalized in all the bins. Bin 1, the open bin, seems to have been protected by its surface layer of slack fully as well as the others were by the roof of the bins.

The seemingly greater loss of heat value at this nine months' stage in bins 1, 2, and 3 than was shown two years later in the same bins is easily explained by the fact that the nine months' samples were grab samples taken 8 to 12 inches below the surface, where greater weathering could occur, whereas the 2¾-year samples were representative of the entire lot in each bin and included parts from the interior that were scarcely weathered at all.

After 2¾ years bin 4, the deep closed bin, showed the greatest loss, 5.26 per cent; then followed, in order, bin 5, 4.96 per cent; bin 3, 3.99 per cent; bin 2, 3.75 per cent; and bin 1, 3.19 per cent.

CONCLUSIONS.

Evidently Sheridan coal under the conditions of these tests loses 3 to 5.5 per cent of its heat value in about three years' storage, the greater part (70 to 80 per cent) of this loss being in the first nine months. During the period of 2¾ years the deep bins suffered the greatest loss, probably because their sides offered greater surface for access of air than those of the small bins. The latter became covered with a 12-inch layer of fine slack that helped to protect the layers beneath from oxidation. In the deep bins, the lumps became badly cracked, but retained their form sufficiently to give more ready access of air, and thus permit greater oxidation.

In the storage of Sheridan coal for more than three months, covering the bins is not as advantageous as the use of air-tight bottoms and sides (of concrete, for example), and the accumulation of a protecting layer of fine slack on the surface. The deterioration of Sheridan coal in heat value can probably in this manner be kept below 3 per cent in one year, and will probably not increase to more than 4 per cent in two or three years if the coal remains undisturbed.

Physical deterioration (slacking) is also largely prevented in the under portions by the formation of a closely packed layer of slack, at least 12 inches thick on the surface.

Although no indications of spontaneous heating were noted in the tests herein described, it is found in practice to be dangerous, on account of dangerous heating, to store Sheridan coal in piles greater than about 10 feet in depth or width. In large masses of coal radiation of spontaneously developed heat is restricted to a dangerous degree. Submergence under water would probably prove particularly advantageous as a means of safely storing subbituminous coal of the Sheridan type.

PUBLICATIONS ON THE COMPOSITION OF COAL.

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BULLETIN 85. Analyses of mine and car samples of coal collected in the fiscal years 1911 to 1913, by A. C. Fieldner, H. I. Smith, A. H. Fay, and Samuel Sanford. 1914. 444 pp., 2 figs.

BULLETIN 116. Methods of sampling delivered coal, and specifications for the purchase of coal for the Government, by G. S. Pope. 1916. 64 pp., 5 pls., 2 figs.

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TECHNICAL PAPER 2. The escape of gas from coal, by H. C. Porter and F. K. Ovits. 1911. 14 pp., 1 fig.

TECHNICAL PAPER 5. Constituents of coal soluble in phenol, by J. C. W. Frazer and E. J. Hoffman. 1912. 20 pp., 1 pl.

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TECHNICAL PAPER 140. The primary volatile products of the carbonization of coal; a sequel to Bulletin 1, The volatile matter of coal, by G. B. Taylor and H. C. Porter. 1915. 59 pp., 1 pl., 25 figs.

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Bulletin 137

DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, SECRETARY
BUREAU OF MINES
VAN. H. MANNING, DIRECTOR

THE USE OF PERMISSIBLE EXPLOSIVES IN THE COAL MINES OF ILLINOIS

BY

JAMES R. FLEMING
AND
JOHN W. KOSTER

ILLINOIS COAL-MINING INVESTIGATIONS
COOPERATIVE AGREEMENT

[This report was prepared under a cooperative agreement with the Illinois State Geological Survey and the engineering experiment station of the University of Illinois]

WASHINGTON
GOVERNMENT PRINTING OFFICE
1917

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PREFACE.

In 1911 the General Assembly of the State of Illinois, with a view to safeguarding the lives of mine workers and conserving the mineral resources of the State, authorized an investigation of the mining practices and the coal resources of Illinois by the department of mining engineering of the University of Illinois and the State geological survey, in cooperation with the United States Bureau of Mines. A cooperative agreement [a] was approved by the Secretary of the Interior and by representatives of the State of Illinois.

Reports of the mining practices in the eight districts into which the State was divided, a general summary of mining practices in Illinois, and a report on the general theory of subsidence have been published by the mining department of the University of Illinois. A study of the percentage of extraction of coal is now in progress.

The State geological survey has investigated and published reports on coal analyses and on the coal resources of four districts and will complete reports on the remaining districts. It has also published a report on the evidences of subsidence due to coal mining and another on the availability of roof and floor clays and shales at coal mines for the manufacture of clay products.

The Bureau of Mines has published as a result of this work: Bulletin 72, ''Occurrence of Explosive Gases in Coal Mines''; Bulletin 83, ''The Humidity of Mine Air''; Bulletin 99, ''Mine-Ventilation Stoppings, with Especial Reference to Coal Mines in Illinois''; and Bulletin 102, "The Inflammability of Illinois Coal Dusts."

The study of mine air, mine fires, and the use of explosives is being continued, and the coking and gas-producing qualities of Illinois coals are being investigated. A detailed investigation of subsidence in Illinois is being undertaken jointly by the parties to the agreement.

Van. H. Manning,
Director.

---

[a] For details of agreement see preliminary report on organization and method of investigations: Illinois Coal-Mining Investigations, Cooperative Agreement, 1913, 71 pp.

THE USE OF PERMISSIBLE EXPLOSIVES IN THE COAL MINES OF ILLINOIS.

By James R. Fleming and John W. Koster.

INTRODUCTION.

The following report is made through the Bureau of Mines as a result of the work under the cooperative agreement with the State geological survey and the engineering experiment station of the University of Illinois. It deals with the use of permissible explosives in the coal mines of Illinois, and is intended primarily to present to mining men the possibility of assuring safer conditions in mining through the use of these explosives.

Twenty coal mines in Illinois were using these relatively safe explosives at the time this report was prepared. Of these, seventeen were in Franklin County, two were in Saline County, and one in Montgomery County. In these various fields experience had shown that although black blasting powder was a useful agent in breaking down the coal at the working face, yet it had given such conclusive evidence of its danger to life and property in causing explosions and mine fires that a substitute was sought and has been found in permissible explosives.

Each coal mine in Illinois in which permissible explosives are used was visited and a study made of the problems involved.

The report deals briefly with the dangers of black blasting powder now in such common use in coal mining. It discusses the development of permissible explosives and their introduction into Illinois coal mines and points out the characteristic differences between permissible explosives and black blasting powder. The present system of blasting and the most approved methods of using permissible explosives are described. Data are given to show that not only has safety and efficiency in these mines been greatly improved, but that the cost of explosives to the miner per ton of coal has been reduced, and that sizes of coal produced from permissible explosives compare favorably with those previously obtained at the same mines with black blasting powder. The successful use of permissible explosives in these Illinois mines as well as in many other mines throughout the country should aid in their introduction into a larger number of mines and bring about that degree of freedom from explosions and fires which should be attained in mining.

ACKNOWLEDGMENTS.

The writers desire to thank the officials of the various mining companies and the State and county inspectors for many personal courtesies and for valuable assistance in supplying the data herein contained. Especial acknowledgments are given C. M. Moderwell, president of the Illinois Coal Operators' Association, Frank Farrington, president of district No. 12, United Mine Workers of America, J. E. Jones, State mine inspector for the eleventh district, and James Dunn, superintendent of the Old Ben Coal Corporation, for suggestions and criticisms of the manuscript; to George S. Rice, chief mining engineer of the bureau, for valuable assistance given in personal supervision of the work; to Frank W. De Wolf, director of the Illinois State Geological Survey, H. H. Stoek, head of the department of mining engineering, University of Illinois, and H. I. Smith, district mining engineer of the bureau, for active cooperation; to S. P. Howell and W. C. Cope, of the explosives section of the bureau, for information on details of the work covered by their respective departments; and to J. J. Rutledge, mining engineer of the bureau, for certain field data.

THE COAL FIELDS OF ILLINOIS.

COAL RESERVES.

As reported by the Illinois State Geological Survey, the coal reserves of the State approximate 200,000,000,000 (short) tons,[a] a supply sufficient to meet the entire Nation's needs for more than 200 years at the present rate of consumption, allowing for only a 50 per cent recovery of coal. There are five workable seams of commercial importance. The territory underlaid with coal embraces approximately 36,800 square miles, or 65 per cent of the area of the State.

PRESENT PRODUCTION.

During the fiscal year ended June 30, 1915,[b] the mines of Illinois produced 57,601,694 tons of coal. Of this total, the No. 6 seam furnished 69.63 per cent and the No. 5 seam 20.21 per cent. These two seams, which include all the mines now using permissible explosives, therefore furnish about 90 per cent of the total output of the State.

METHODS OF MINING.

There are three general methods of mining coal in the State of Illinois, as follows:

1. Stripping.
2. Longwall advancing.

---

[a] Preliminary report on organization and method of investigations: Illinois Coal-Mining Investigations, Cooperative Agreement, 1913, p. 25.

[b] Thirty-fourth annual coal report of Illinois, State Mining Board, 1915, p. 86.

3. Room-and-pillar:
   - *a.* Common double-entry, room-and-pillar system.
   - *b.* Panel system.

In stripping operations the dangers of explosions and fires are not found as in underground workings.

In the longwall mines the roof pressure usually takes the place of explosives in breaking down the undercut face.

The room-and-pillar mines, including the common double-entry, room-and-pillar system and also the panel system, provide 94 per cent of the total output of the State. Coal undercut by machines constituted 59.1 per cent [a] of the total State production in 1915. The greater part of the remainder was from mines in which the coal was shot off the solid. In a few mines undercutting is done by hand.

AMOUNT OF EXPLOSIVES USED IN ILLINOIS MINES AND TONNAGE PRODUCED.

For the fiscal year ended June 30, 1914, a total of 60,715,795 short tons of coal was produced in Illinois. Of this amount approximately 56,400,000 tons was obtained with the use of explosives. To obtain this production, 31,607,200 pounds of black blasting powder and 930,596 pounds of permissible explosives were used. Although the amount of permissible explosives formed only 3 per cent of the total quantity of explosives used, approximately 6,000,000 tons of coal, or more than 10 per cent of the total quantity obtained by explosives, was obtained by the use of permissible explosives.[b]

During the fiscal year ended June 30, 1915, of the total of 57,601,694 short tons of coal produced, approximately 53,600,000 tons was obtained with the use of explosives, 27,683,150 pounds of black blasting powder and 1,342,334 pounds of permissible explosives being used.[c] In this year approximately 7,680,000 tons of coal, or 14.3 per cent of the total quantity obtained by explosives, was produced by the use of permissible explosives. The tonnage produced by permissible explosives is divided approximately as follows: Franklin County, 86 per cent; Saline County, 7 per cent; Montgomery County, 7 per cent.

Figure 1 shows the total production of coal, the amount of black blasting powder used during the period 1907–1915, and the gradual increase in the amount of permissible explosives used in Illinois mines. The figure also shows that the tonnage now produced by permissible explosives exceeds that of longwall mining. The data from which these curves were plotted, given in the table following,

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[a] Computed from thirty-fourth annual coal report of Illinois, State Mining Board, 1915 (p. 69), which shows that 97 mines used machines exclusively, and 34 in part, a total of 1,686 machines being used in producing 34,037,426 tons of coal.

[b] Thirty-third annual coal report of Illinois, State Mining Board, 1914, p. 2.

[b] Thirty-fourth annual coal report of Illinois, State Mining Board, 1915, p. 2.

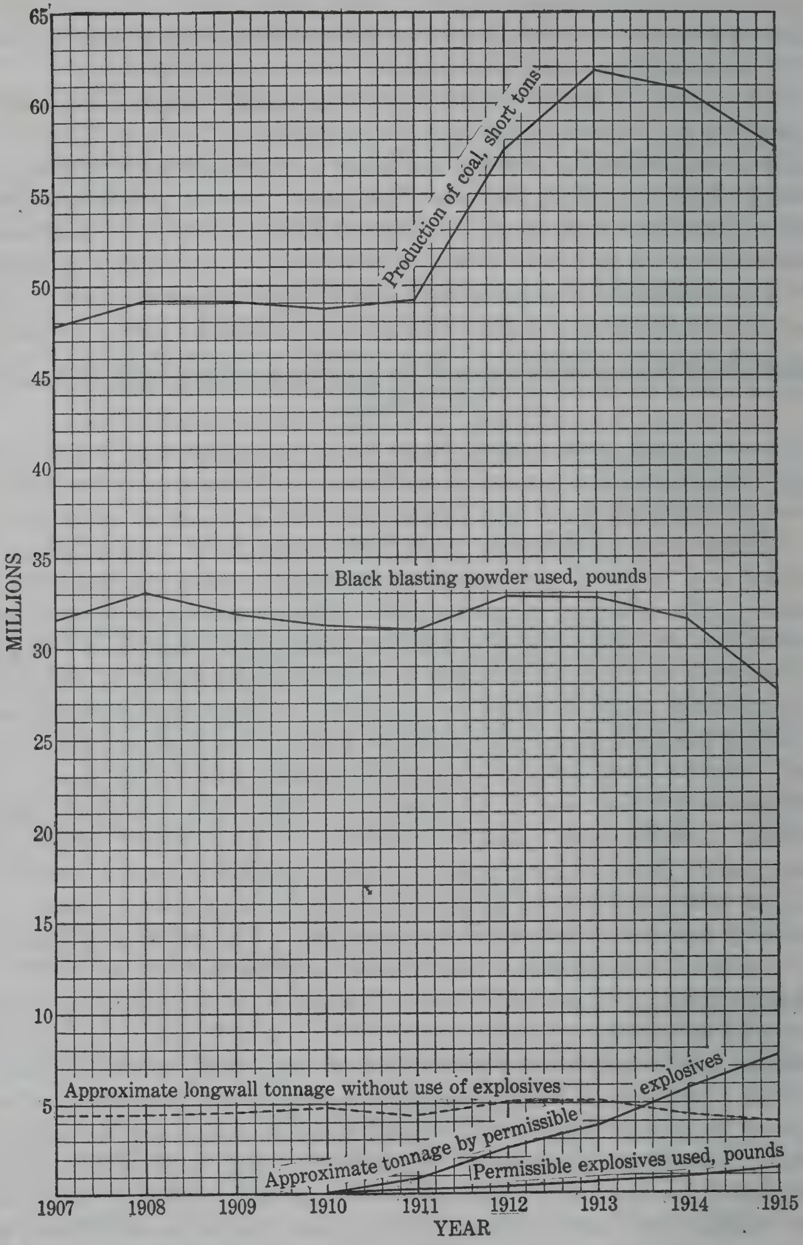

FIGURE 1.—Curves showing the production of coal in Illinois, amount of explosives used, and growth in the use of permissible explosives during the period 1907–1915.

are taken from the annual coal reports of the State of Illinois for the years 1907 to 1915.

Data on the production of coal and use of explosives in Illinois coal mines, 1907–1915.

Year.	Production of coal.	Black blasting powder used.	Approximate longwall tonnage without the use of explosives.	Approximate tonnage by permissible explosives.	Permissible explosives used.
	Short tons.	*Pounds.*	*Short tons.*	*Short tons.*	*Pounds.*
1907	47,798,621	31,547,750	4,500,000	....	....
1908	49,272,452	33,211,350	4,500,000	....	....
1909	49,163,710	32,015,175	4,600,000	....	....
1910	48,717,853	31,352,375	4,800,000	....	....
1911	50,165,099	31,007,325	4,400,000	900,000	243,099
1912	57,514,240	32,836,200	5,200,000	2,580,600	328,075
1913	61,846,204	32,734,550	5,200,000	3,847,000	603,420
1914	60,715,795	31,607,200	4,400,000	5,926,400	930,596
1915	57,601,694	27,683,150	4,000,000	7,680,000	1,342,334

PHYSICAL CHARACTERISTICS OF COALS NO. 5 AND NO. 6.

The character of the coal and roof and the thickness of the coal bear an important relation to the system of blasting that should be used; the presence of explosive dust and gas makes a problem needing especial consideration. The mines in which permissible explosives are used in Illinois are confined to coals No. 5 and No. 6. A brief description of the occurrence of these coals in the particular districts in which permissible explosives are used—Saline, Franklin, and Montgomery Counties—follows:

Coal No. 5 where mined has an average thickness of 5 feet 4 inches with a maximum thickness of 8 feet in Saline County. It is reported by DeWolf [a] to average 4 feet 11 inches in the Saline-Gallatin field in 56 measurements. The coal is hard and bright with occasional partings of soft "mother of coal." Usually the top and bottom parts of the bed are harder and firmer than the middle part. A few bands or patches of "sulphur" may occur near the top. The cleat is not pronounced and does not materially affect the direction of mining. The roof is hard shale, varying from light gray to black; it holds well and does not require excessive timbering. It is characterized by numerous concretions of iron pyrites called "nigger heads." The floor is clay.

Coal No. 6 as it is found in southern Illinois is described by Shaw and Savage [b] as being uniformly thick, averaging 9 feet 5 inches in 130 borings. At Zeigler it has a thickness of 14 feet. The coal is commonly banded, and laminated with alternating bright and dull lines. A "blue band," or dirt band, ½ to 2½ inches thick, occurs

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[a] DeWolf, Frank W., Coal investigations in the Saline-Gallatin field, Illinois: Bull. 8, State Geol. Survey, 1908, pp. 223–224.

[b] Shaw, E. W., and Savage, T. E., Murphysboro-Herrin Folio, Illinois, surveyed in cooperation with the Geological Survey of Illinois, Folio 185, U. S. Geological Survey, 1912, p. 14.

18 to 30 inches above the floor; this band generally consists of bone or of gray shale.

The bed is divided into three distinct benches. The upper part, comprising about one-third of the thickness of the bed, is a brittle coal occurring often in layers 3 to 6 inches thick, separated by partings of "mother of coal." The coal in the middle part, which is separated from the upper third of the bed by a clean persistent parting of "mother of coal," is brighter and somewhat firmer and has less distinct lamination. "Sulphur" lenses are commonly found in this bench. Below the "blue band" the coal is hard and firm.

The coal in the southern part of the Franklin County field is harder than the coal in the northern part. There is no pronounced cleat and, therefore, it does not materially affect the direction of mining, as the coal may break irregularly along a number of different planes. In certain mines, however, there is a slight vertical cleat in a northeast and southwest direction, which permits freer shooting of the coal on a face parallel with this direction. Although the cleat of the coal has little effect on the direction of mining, the joints in the roof material have; for frequently when work is driven north or south the roof tends to break so much as to increase mining costs considerably.

The "blue band," which is characteristic of the No. 6 coal, largely determines the placing of drill holes in blasting. After the coal is undercut by machines, it is "snubbed"; that is, a sloping cut extending from the "blue band" to about half the depth of the undercutting is made. When "snubbing" shots are fired or where "snubbing" is done by hand, this parting serves as a guide to the height to which the coal is to be "snubbed."

The roof is commonly of shale, which is 15 to 110 feet thick, but in some of the latest mines east of Benton, limestone is found immediately above the coal. The shale breaks when exposed, and for this reason the top layers of coal are left in place to form the roof. Usually 10 to 18 inches and at times as much as 40 inches is left up. In some instances the top coal is recovered after the rooms are mined out. The floor is clay.

Plate I [a] shows the No. 6 coal bed and the overlying shale exposed, the top bench of coal (dark part) which is left up in mining, and the two lower benches separated by the "blue band," which occurs about 2 feet from the bottom. The structure of the lower 5 feet of the No. 6 coal bed, including the blue band, is shown in Plate II, *A*.

In Montgomery County, the characteristic "blue band" is present. The coal is hard and firm and averages about 7½ feet thick. The roof is shale and limestone. Where light-colored shale is present

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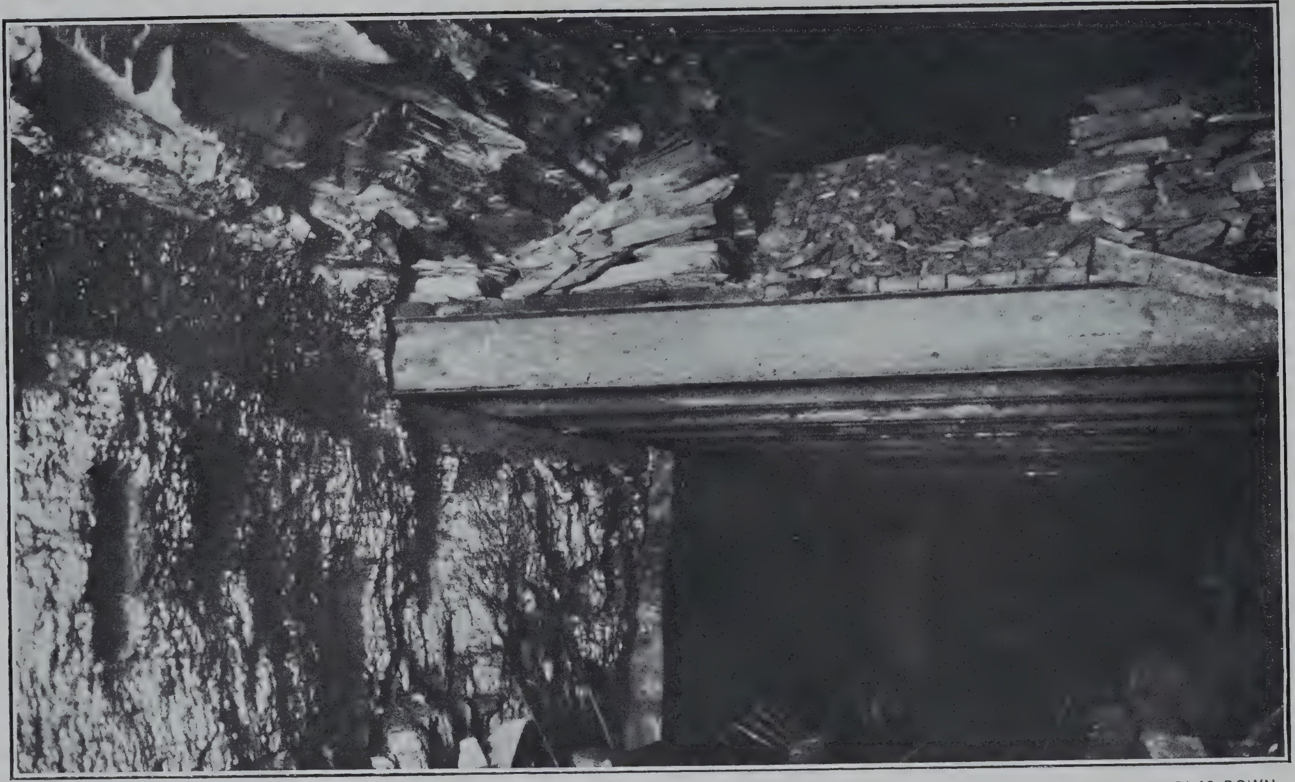
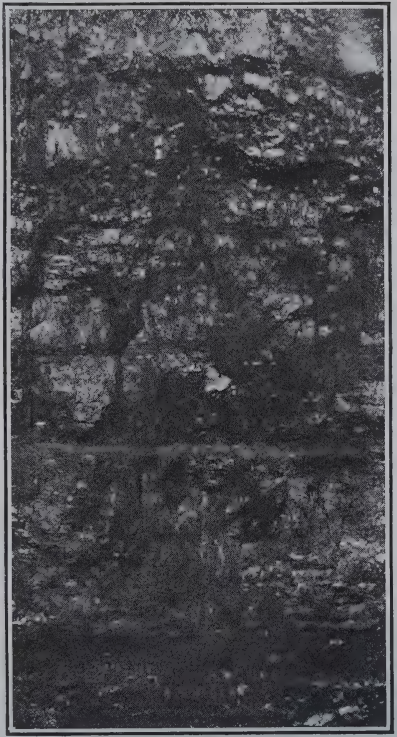
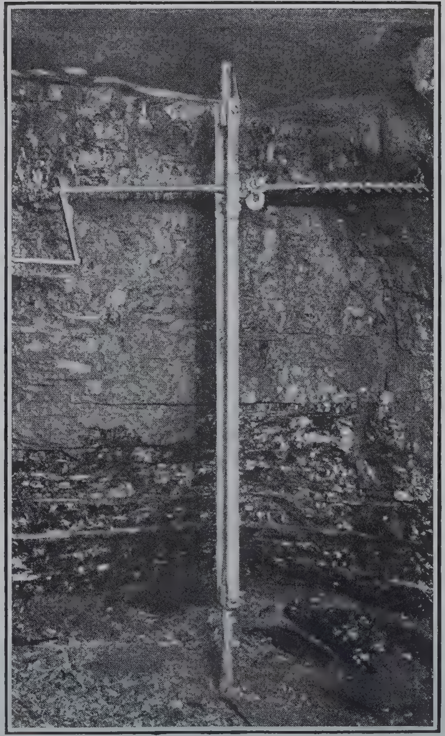
[a] Cady, G. H., Coal resources of District 6: Illinois Coal-Mining Investigations, State Geol. Survey Bull. 15, 1916, p. 92.



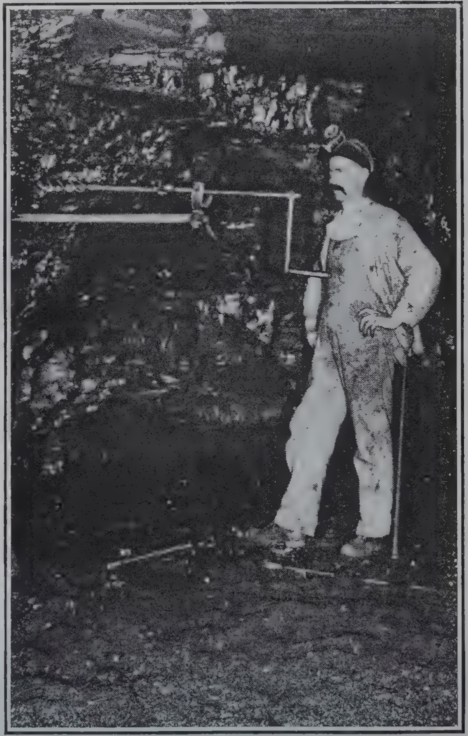
BROKEN ROOF IN ENTRY OF AN ILLINOIS MINE. CONDITIONS TYPICAL OF NO. 6 BED WHEN THE SHALE OVERLYING THE COAL BREAKS DOWN.



A. LOWER 5 FEET (TWO BOTTOM BENCHES) OF NO. 6 COAL IN FRANKLIN COUNTY. BLUE BAND JUST BELOW CENTER OF PICTURE.



B. POST DRILL, USED IN ILLINOIS COAL MINES.



C. GRIP DRILL, USED IN ILLINOIS COAL MINES.

it forms a good roof. Where the roof is dark shale the top bench of coal, 15 to 18 inches thick, is left in place. The coal is underlain with a bed of clay 4 to 50 inches thick.

The coal as mined from these beds is uniformly hard and firm and withstands shipment well, especially in the smaller sizes, and is well adapted for domestic or steam fuel.

OCCURRENCE OF GAS IN THE COAL BEDS.

In Franklin County, coal bed No. 6 lies at a depth ranging from 417 to 700 feet.[a] The part of the southern Illinois coal field east of the Duquoin anticline, including Franklin, Williamson, and Saline Counties, is the most gaseous in Illinois. Although on the whole the mines are not regarded as being gaseous enough to require the use of locked safety lamps, yet considerable methane is given off from the coal. Numerous local faults occur in both No. 5 and No. 6 seams, frequently giving off local feeders of gas and creating the possibility of dangerous accumulations. Darton [b] found that the principal mines in Franklin County in 1912 generated on an average about 200 cubic feet of methane per minute under normal working conditions. In the more gaseous areas, immediately above the coal there is a considerable thickness of impervious shale, whereas in the less gaseous districts in which the same seams are mined, jointed limestone closely overlies the coal.

The results of laboratory tests [c] indicate that the dust from the No. 6 coal bed is highly inflammable as compared with other Illinois coal dusts and when raised in a cloud might be ignited by a blown-out shot of black blasting powder. Considerable fine rib dust is nearly always in evidence in the mines in the No. 6 bed. As the top coal is left in place, and shale from the roof does not fall on the roadways, and as haulage is by electricity, so that the bottom clay is not ground up much by the feet of men and animals, the road dust consists almost wholly of coal dust.

CAUSES LEADING TO THE USE OF PERMISSIBLE EXPLOSIVES IN ILLINOIS.

DEVELOPMENT OF THE FRANKLIN COUNTY COAL FIELD.

In the Franklin County field, where the use of permissible explosives in Illinois was begun, mining is comparatively recent. The field was opened at Zeigler in 1903. Mines were developed at West Frankfort, Benton, Christopher, and other points in Franklin County, until at the present time this field ranks as one of the important bituminous coal areas in the United States. New mines are being developed.

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[a] Average depth at shaft for mines listed is 541 feet, see Table 1, p. 22.

[b] Darton, N. H., Occurrence of explosive gases in coal mines: Bull. 72, Bureau of Mines, 1915, p. 219.

[c] Clement, J. K., Scholl, L. A., The inflammability of Illinois coal dust. Bull. 102, Bureau of Mines.

The Franklin County mines in which permissible explosives are used have an average daily production of approximately 2,800 tons. Six of these mines have a daily capacity of over 4,000 tons each. Of the total of 57,601,694 short tons of coal produced in Illinois for the year ended June 30, 1915, 7,324,644 tons was produced in this county, of which about 90 per cent was shot down with permissible explosives.

EXPERIENCE IN FRANKLIN COUNTY WITH BLACK BLASTING POWDER.

The first mines in Franklin County were opened when black blasting powder was the only practical coal-mine explosive used in the United States. From the beginning much trouble was experienced with mine fires caused by its use. The gaseous conditions in this field, the extremely inflammable nature of the coal dust, the methods of mining, by which 10 to 40 inches of coal left for roof spalled onto the roadways and produced dust, all combined to make the use of black blasting powder dangerous and costly as regards life and property.

A number of destructive explosions happened in Franklin County in 1908 and 1909. Such occurrences were not confined to any particular mine, although certain mines had more than one, but were scattered over the entire field. Furthermore, every mine in the district suffered from frequent fires from the use of black blasting powder, the coal igniting readily and there being some methane liberated at the face. At some mines as many as twenty fires occurred nightly, following the firing of shots, and in two instances 40 were reported. The employment of fire runners to follow the shot firers and extinguish fires became necessary. Four to ten men were employed for this work at each of the various mines, and the relatively small number of fires getting beyond control speak well of the efficiency and carefulness of these men and of the officials.

At one mine in this district two destructive coal-dust explosions, primarily caused by firing shots of black blasting powder, occurred in an interval of about six weeks, the first on November 5, 1908, and the second on December 12, 1908. Immediately after the first explosion the governor of the State ordered that a thorough examination of conditions in this mine be made by the State inspectors of mines and the State mining board. That the explosion was initiated by a shot and was accompanied with much flame and violence is pointed out in the following extract from the report of this committee.[a]

> Several tests with safety lamps were made on the roadways, at the face of the working places, and particularly at the high points where falls of "slate" had occurred, but no evidence of gas was discovered. After reaching the face of the first northeast entry

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[a] Twenty-eighth annual coal report of Illinois, State Bureau of Labor Statistics, 1909, p. 372.

beginning with room No. 20, we proceeded down until No. 8 was reached. As we approached that point, indications of serious disturbances increased—falls of "slate" and coal crushed from pillars, broken timbers, mining machines, and pit cars completely destroyed. From the mouth of room No. 8 and continuing up to the face thereof, evidences of intense heat and fire on the roof and props were observable. At the face of that room we found that several shots had been fired on the night of the explosion; in fact, they were the only shots fired in any of the rooms in that entry that evening. It furthermore appeared that the shots had been placed near the top of the coal, and as the seam of coal is much softer near the roof much of it that was blown down was in a badly shattered condition. There is no question but that the direct cause of the explosion originated from these shots in the face of room No. 9, first northeast entry; that the placing of these shots so near the roof and the broken condition of the coal indicated an overcharge of powder. * * * In order to avoid a repetition of such disasters, we recommend that in all cases where coal is undercut with chain machines, the coal be snubbed or blocked down at not more than 3, or less than 2, feet from the bottom of the seam, and that all undercuttings produced by said machines be collected and loaded out before any shots are fired.

An explosion at shot-firing time also occurred shortly thereafter at a mine near Benton and another in a mine near West Frankfort. Fortunately, large loss of life was prevented, as the miners were out of the mine at the time, there being a State law requiring that all men except shot firers should be out of the mine during shot firing.

Data as to the costs of these destructive explosions throughout the field are not obtainable, but a heavy expense must be charged against explosions and fires from the use of black blasting powder. In one of the accidents mentioned above, the mine was practically new, and had shipped only about 150,000 tons of coal, when an explosion occurred at shot-firing time, which killed the shot firers and set the mine on fire, the flames reaching the top of the hoisting shaft and preventing any recovery operations. Both shafts had to be sealed. The shafts were kept sealed for 120 days and later the mine was flooded.[a] Shipments of coal were suspended for a period of over a year while the mine was being restored. The total loss due to flooding, suspension, and restoring the mine to working condition was upward of $175,000.

AGREEMENT BETWEEN FRANKLIN COUNTY OPERATORS AND MINERS.

A feeling of extreme uneasiness existed at this time, and operators and miners considered means that might end such disasters. This crystallized in the agreement between Franklin County operators and miners, which commendably aimed to improve the methods of using black blasting powder. As the recommendations contained in this agreement were a step forward and illuminate some special features of preparing the coal face preliminary to shooting, they are given below. "Snubbing" of the coal, the loading out of machine cuttings prior to blasting, tamping the shot holes with clay and not with coal dust or cuttings, prescribing that the drill holes be not nearer than 12 inches to the ribs of the working place, and shorter by 10 inches than the depth of the undercutting are all good rules to-day for use in shooting with permissible explosives in this field. The agreement was as follows:

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[a] Twenty-eighth Annual Coal Report of Illinois, State Bureau of Labor Statistics, 1909, p. 375.

AGREEMENT RELATIVE TO PREPARATION OF FACE FOR BLASTING IN FRANKLIN COUNTY MINES.[a]

1. That the bits used in the Franklin County chain-machine mines be the maximum width of 2¼ inches, on a 6-foot bit, and the length not more than 6 feet.
2. That a minimum of 25° and a maximum of 45° holes across the face be drilled for the "buster" shots, and no more than two holes be fired in all wide working places in one shift, unless more holes are required to furnish coal for the day's work.
3. We recommend that all coal be "snubbed" with pick and wedge.
4. That "snubbing" means that the coal must be snubbed not lower than the height of the blue band and back one-half the depth of the cutting, and all coal snubbings must be removed from underneath.
5. That all cuttings from the electric chain machine be loaded out before any shots are fired in the working places, the company to furnish cars promptly for loading same.
6. That all drill holes be tamped with clay, the company to furnish clay when it is impossible for the miner to obtain the clay within a distance of 300 feet of his working place.
7. That all shots, when shot by shot firers, shall be inspected before being tamped, and a vigilant watch on all shots be kept by the shot firers, and any excessive use of powder used in any holes by the miner and any dangerous holes be reported to the mine manager, and said miner shall be discharged.
8. That all holes be tamped on a copper needle, unless holes be wet, and we recommend that no shots be fired with fuse.
9. That no holes be drilled until after the working places are cut, only in emergency cases, then "buster" shots may be drilled, and all rib holes must be drilled so the powder will lay no closer than 12 inches of the rib of the working place, and all holes must be drilled at least 10 inches less than the depth of the cutting, thus giving the powder a chance to work.

Separate Clause.

In case the "snubbing" is done with powder, it is understood that the snubbing holes shall not be more than 2 feet 10 inches above the top of the cutting, and that said snubbing shall extend the entire width of the place and shall be loaded out to within 2 feet of the back of the cut, provided the snubbing of coal by pick and wedge can not be agreed upon by the joint boards.

NEED OF A SUBSTITUTE FOR BLACK BLASTING POWDER.

The spirit of the foregoing agreement indicates an earnest desire on the part of the mining fraternity to cope with the problems presented. The results, although showing an improvement over previous conditions, were unsatisfactory. The relief was partial. Fires continued to occur at shot-firing time, and the explosion in the mine at Benton when solid shooting was in vogue was repeated later after mining machines were installed. A violent explosion occurred at one mine from a shot which was apparently properly placed with less than two pounds of powder in undercut coal. It was seen that although black blasting powder was an effective agent in the production of coal, yet its characteristic long hot flame rendered it unsafe in these mines, even when used by expert miners under stringent regulations.

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[a] Adopted in January, 1909.

The problem of mine fires and explosions has not been confined to Illinois. In all bituminous coal mines, especially where explosive gas and dust have been present, the need of a substitute for black blasting powder has been evident. As early as 1854 the problem was demanding attention. In that year the London Mining Journal referred to the testimony of Mr. George Elliot, a witness examined by the Parliamentary Committee,[a] as follows:

> "A very painful accident happened at Usworth Colliery, of which I was owner and manager, some time since, and which arose from fire of shot; and since that Mr. Lee Pattinson, a practical chemist, and myself have been endeavoring to ascertain whether we could invent some power to bring coal down without an explosive mixture, such as gunpowder; and I am sorry to say that no very successful result has yet been arrived at; but up to the present time, I am afraid, notwithstanding gunpowder is a very old chemical invention, that very little progress has been made since it was first used and that we are in ignorance of any substitute for it of equal power. If public attention were called to it, perhaps science might discover some substitute."
>
> And as this journal had previously solicited public notice as to the subject, we again repeat that the researches of chemical and electrical discovery, which have in our times produced such marvelous results, could not be devoted to a nobler object of scientific ambition.

Although statistics of the past 27 years show that only 15.4 per cent of all fatal accidents in the coal mines of Illinois[b] have been caused by explosives or by explosions of gas or coal dust due to firing of shots or other initiating cause, yet mine explosions are nevertheless dreaded because of their far-reaching effects. The conditions that exist in coal mines tend to make explosions a menace to the lives of everyone in the mine, and therefore any factor or combination of factors that might form the initiating causes should be carefully controlled. The most careful man in the mine may meet his death through no fault of his own, but through the carelessness or thoughtlessness of a fellow workman. Miner and operator are alike affected by the dangers of using long-flame explosives such as black blasting powder, in gaseous and dusty mines.

Experiments during the past few years have conclusively proved that:

1. The flames of black blasting powder and of dynamite readily ignite an inflammable mixture of methane and air.

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[a] Report of the Parliamentary Committee on Accidents in Mines, London, 1854.

[b] Editorial, London Mining Journal, 1854, vol. 24, p. 315.

[c] Thirty-third annual coal report of Illinois State mining board, 1914, p. 105.

2. An explosion of coal dust can be initiated by a single blown-out shot from black blasting powder at the face.[a]

3. The amount of coal dust, suspended in the air, that may propagate an explosion may be very small. Taffanel, in France, obtained explosions regularly with 190-mesh bituminous dust with a weight of 0.07 ounce per cubic foot of dust cloud. In experiments in the gas and dust gallery No. 1 at the Pittsburgh station of the Bureau of Mines, propagations have been obtained with 200-mesh dust from the Pittsburgh coal seam with as low a weight as 0.032 ounce per cubic foot of gallery space.[b]

4. As little as 1 to 1½ per cent of methane,[c] an amount that may often be present without being detected with the safety lamp, will, as has been shown by tests of the Bureau of Mines, greatly increase the explosibility of coal dust.

With these facts available, it should be apparent that the use of black blasting powder and dynamite will always be an element of danger where gas and coal dust are present. The concussions from the shots in the various parts of the mine cause the supposedly harmless road and rib dust to become suspended in the air, and then a blown-out shot, or even an overcharged or undercharged shot, may initiate an explosion. It may be possible to estimate the number of actual explosions that have occurred in a particular mining district, but there are no means of determining how many explosions were prevented only by the absence of only one contributory factor or by the presence of some hindering influence. Freedom from explosions in certain mines in which black blasting powder is used, where conditions are known to border on the dangerous, is not because of systems in vogue, but in spite of them.

There is no absolute guaranty against mine explosions from black blasting powder happening even in nongaseous mines. In addition to data obtained from tests at the experimental mine of the bureau there is other proof. For example, an explosion occurred at shot-firing time in a mine in the Springfield district, Ill., in March, 1915, which killed two shot firers, although no previous trouble had been experienced in 17 years of operation. Analyses of return air at this mine show that methane is not present in appreciable percentages. A coal-dust explosion happened at a mine in the Peoria district, in February, 1915, during the firing of shots of black blasting powder by the night shift. Two entrymen who had lighted the shots and were on their way out of the mine were killed.

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[a] The standard method of initiating an explosion at the Bureau of Mines experimental mine near Pittsburgh, Pa., is by firing from a cannon a charge of 4 pounds of FFF black powder stemmed with dry clay producing a blown-out shot, in the presence of finely ground coal dust distributed in quantities of 2 pounds per linear foot. This quantity (4 pounds) of black powder is used to insure strong initial explosion of the coal dust, but in some experiments only 2 pounds has been used, placed in a drill hole in the face in solid coal, the single shot causing a violent dust explosion. Coal-dust explosions have been caused by black powder shots when the loading of coal dust was only 0.3 pound per linear foot of entry, which is equivalent to only 0.083 ounce per cubic foot of space. This test was made with finely ground coal dust. Coal dust that is all fine impalpable dust is most highly explosive and behaves much like an inflammable gas when raised in a cloud in the air and ignited. See Rice, G. S., and others, First series of coal-dust explosion tests in the experimental mine, Bull. 56, Bureau of Mines, 1913, 113 pp.

[b] Rice, G. S., Explosibility of coal dust, Bull. 20, Bureau of Mines, 1911, pp. 101–102.

[c] Rice, G. S., and Jones, L. M., Methods of preventing and limiting explosions in coal mines: Tech. Paper 84, Bureau of Mines, 1915, p. 7.

DEVELOPMENT OF SHORT-FLAME OR "PERMISSIBLE" EXPLOSIVES.

The first steps in the manufacture of permissible explosives date back about 30 years. As stated by Rice,[a] research was begun in Germany in 1885 for the development of explosives "Which would not ignite fire damp and coal dust under ordinary conditions," and in the coal-mining countries of Europe, including England, France, Germany, Belgium, and Austria, it is now required that only such explosives shall be used in coal mines as have passed certain tests or have met certain requirements.

So-called "safety" blasting powders were introduced into the bituminous coal fields of Pennsylvania and West Virginia in 1902, but it was not until 1908, soon after the establishment of the Pittsburgh testing station of the Bureau of Mines where testing of explosives [b] for use in gaseous and dusty mines was begun, that an impetus was given to the manufacture and use of such explosives in the United States. Since that time constant effort has been made by manufacturers to improve the qualities of their products, with the result that many of the early brands have been withdrawn from the market and their places taken by better ones. The February, 1917, list of explosives contains the brand names of 153 "permissible" explosives.[c]

WHAT IS A PERMISSIBLE EXPLOSIVE?

It should be noted that an explosive is called a "permissible explosive" when it is similar in all respects to the sample that passed certain tests [d] by the Bureau of Mines, and when it is used under the following conditions:

1. That the explosive is in all respects similar to the sample submitted by the manufacturers for the test.

2. That detonators—preferably electric detonators—are used of not less efficiency than those prescribed, namely, those consisting by weight of 90 parts of mercury fulminate and 10 parts of potassium chlorate (or their equivalents).

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[a] Rice, George S., The explosibility of coal dust: Bull. 20, Bureau of Mines, 1911, pp. 82–83.

[b] Systematic tests of permissible explosives began early in 1909 at the experiment station at Pittsburgh. The first list of explosives passing the tests was published by the bureau May 15, 1909.

[c] Fay, A. H., Coal-mine fatalities in the United States during February, 1917, and list of permissible explosives, lamps, and motors tested prior to March 31, 1917, 24 pp.

[d] For details of character of tests see pp. 101, 102 of this report, and Schedule 1, Fees for testing explosives and conditions and requirements under which explosives are tested, Bureau of Mines, 1913, 8 pp. For a detailed description of the methods used see Hall, Clarence, and Howell, S. P., Tests of permissible explosives, Bull. 66, 1913, 313 pp.; Storm, C. G., The analysis of permissible explosives, Bull. 96, 1916, 88 pp.

3. That the explosive, if frozen, shall be thoroughly thawed in safe and suitable manner before use.

4. That the quantity used for a shot does not exceed 1½ pounds (680 grams), and that it is properly tamped with clay or other non-combustible stemming.

The general subject of permissible explosives has been treated in various publications[a] of the Bureau of Mines.

Further explanation from the chemist's point of view as to what constitutes a permissible explosive is given in the following statement by C. G. Storm,[b] former explosives chemist of the Bureau of Mines:

> Permissible explosives are blasting explosives that, having passed certain tests prescribed by the Bureau of Mines, are considered suitable for use in gaseous or dusty coal mines when used in the manner prescribed by the bureau. The chief characteristics that an explosive must possess in order to pass the tests are: (1) Relatively low flame temperature on explosion, (2) a minimum amount of explosion flame. Mixtures of natural gas and air are exploded when exposed to a temperature of about 650° C. for about one-tenth of a second, but are not acted upon by flame of much higher temperature if the flame is of sufficiently short duration. Thus, although the flame temperature of most permissible explosives lies between 1,500° and 2,000° C., they do not ignite the most explosive mixtures of gas and air because of the rapidity of their explosion, the duration of their flame being only about two to five ten-thousandths of a second. Black blasting powder, on the other hand, has a flame temperature of over 2,200° C., and a duration of flame, under the same conditions of test, of approximately one second. Ordinary 40 per cent nitroglycerin dynamite gives a flame duration of only about four ten-thousandths of a second, but its flame temperature is about 2,900° C. Both black blasting powder and dynamite, then, fail to pass the tests for permissibility, black blasting powder because of the long duration of its flame and dynamite because of the high temperature of its flame.
>
> The problem in producing permissible explosives is therefore to formulate explosive mixtures that, while giving a minimum amount of flame of short duration and low temperature, will develop sufficient energy to do the work of breaking down coal in an economical manner. An example is cited below:
>
> By proper additions of various ingredients, ordinary dynamite can be so altered in composition that its flame temperature will be reduced sufficiently to render the resulting explosive "permissible." If, for example, a large excess of carbonaceous combustible material, such as wood pulp, flour, or corn meal, is added, the gaseous products of explosion are so altered that the flame temperature is greatly reduced. The same effect is obtained by the addition of water, either in the liquid state, in which form it is absorbed by the other ingredients of the explosive, or in the form of water of crystallization in such crystalline salts as alum, or magnesium sulphate, both of which con-

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[a] Rutledge, J. J., and Hall, Clarence, The use of permissible explosives, Bull. 10, 1912, 34 pp. Hall, Clarence, Snelling, W. O., and Howell, S. P., Investigations of explosives used in coal mines, 1911, 197 pp. Munroe, C. E., and Hall, Clarence, A primer on explosives for coal miners, Bull. 17, 1911, 61 pp. Hall, Clarence, and Howell, S. P., Tests of permissible explosives, Bull. 66, 1913, 313 pp. Munroe, C. E., and Hall, Clarence, A primer on explosives for metal miners and quarrymen, Bull. 80, 1915, 125 pp. Storm, C. G., Tests of permissible explosives, Bull. 96, 1916, 88 pp. Watteyne, Victor, Meissner, Carl, and Desborough, Arthur, The prevention of mine explosions, Tech. Paper 21, p. 7. Fay, A. H., Production of explosives in the United States during the calendar year 1912, Tech. Paper 69, 1914, 8 pp. Fay, A. H., Production of explosives in the United States during the calendar year 1913, Tech. Paper 85, 1914, 15 pp. Howell, S. P., Permissible explosives tested prior to Mar. 1, 1915, 16 pp. Fay, A. H., Production of explosives in the United States during the calendar year 1914, with notes on coal-mine accidents due to explosions, 1915, 16 pp. Fay, A. H., Monthly statement of coal-mine fatalities in the United States.

[b] Storm, C. G., In communication to the Bureau of Mines, July, 1914.

tain about 50 per cent of water of crystallization. Similarly, the addition of inert solid matter, such as clay or powdered rock, which simply absorbs part of the heat liberated by the explosive reaction, or of readily volatile inert materials such as certain ammonium salts, which consume heat in being volatilized, will also produce the characteristics of permissible explosives.

Although such additions naturally lower the strength of the explosive, it is possible to obtain the desired end and still produce explosives entirely suitable for use in coal mining, as is evidenced by the fact that there are at present (July, 1914) about 125 explosives on the "permissible list."

Careful chemical analyses are made of every explosive received for test, in order to determine whether the explosive possesses any objectionable chemical features. Field samples, collected from time to time, are also analyzed in order to ascertain whether the different permissible explosives are being manufactured in accordance with the composition of the original sample submitted for test.

The difficulties encountered by the chemist in analyzing such explosives may be realized when it is known that the manufacturers use a great variety of ingredients in bringing about the desired results. About 60 to 70 ingredients have been found in the various permissible explosives analyzed in the bureau laboratory.

This short duration of flame may be more clearly expressed to the man at the working face by two simple illustrations:

The finger of one's hand after moistening may be touched against a red hot stove or iron without any sensible effects, if the removal action is sufficiently quick. The flame of a burning match may be rapidly passed over a grain of powder or a match head without causing ignition. In either instance, the flame temperature is sufficient to cause burning or ignition, but the time of contact is so short that no effect is produced.

CLASSES OF PERMISSIBLE EXPLOSIVES.

The four general classes of permissible explosives [a] and the characteristic materials of composition are as follows:

Classes of permissible explosives and characteristic material.

Class.	Characteristic material.
Class 1. Ammonium nitrate explosives	Ammonium nitrate.
Class 2. Hydrated explosives	Nitroglycerin with salts containing water of crystallization.
Class 3. Organic nitrate explosives	Organic nitrates other than nitroglycerin.
Class 4. Nitroglycerin explosives	Nitroglycerin.

Of these four types, nitroglycerin explosives are most commonly used in Illinois mines. Nitroglycerin explosives contain free water or an excess of carbonaceous combustible material, which is added to reduce the flame temperature. A few explosives of this class contain salts that reduce the strength and shattering effect of the explosives on detonation. Nitroglycerin explosives have the advantages of detonating easily and of not being readily affected by moisture.

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[a] For detailed description of classes of permissible explosives, see Howell, S. P., Permissible explosives tested prior to March 1, 1915: Tech. Paper 100, Bureau of Mines, 1915, 16 pp.

RATE OF DETONATION.

The rate of detonation may be defined as the rate of explosion, or the rate at which detonation travels through a given length of explosive. When an explosive, which may consist of a solid or liquid substance, or a mixture of substances, is acted upon by a blow or by an initiating compound, such as mercury fulminate, more stable substances, largely or entirely gaseous, are formed almost instantaneously. This conversion process is called detonation, and the rate of detonation is the rate at which the conversion takes place through a given length of explosive. Detonation is more rapid than the transmission of flame from particle to particle, as is the case with black blasting powder.

The rate of detonation is important in relation to the use of permissible explosives in coal mining. It is thought that explosives having an intermediate rate of detonation are best suited for shooting average bituminous coals when undercut. Hall and Howell [a] state that—

> The rate of detonation is the governing factor in judging the efficiency of an explosive, and it offers the best single means for selecting explosives suitable to meet the varying conditions of coal mining.
>
> To meet the varying conditions of coal mining in this country, the explosive manufacturers have devised explosives with rates of detonation that range from 4,750 to 14,560 feet per second.

CHARACTERISTIC ACTION OF EXPLOSIVES.

There is a marked difference in the characteristic action of black blasting powder and that of permissible explosives and other detonating explosives. An understanding of this difference is of assistance in the proper use of permissible explosives.

When laid on top of a rock and exploded, black blasting powder does not materially affect the rock, because it explodes so slowly that the gases formed can lift the air above them and escape; whereas dynamite, if laid on brittle or soft rock and detonated, may shatter it, because the dynamite explodes so quickly that the great volume of gases formed can not lift at once the air confining it and must exert pressure on the rock. This action has given the erroneous impression that dynamite and likewise permissible explosives act downward, rather than upward and outward. Experiments show that the force exerted by an explosive is equal in all directions.[b]

On account of the relatively quick action of permissible explosives, it has also been supposed that no stemming, or very little stemming, is necessary when they are used for shooting down coal. Actual tests have proved that the use of efficient stemming may increase the useful energy of a shot 60 to 93 per cent.[a] Some miners have claimed that merely plugging the mouth of the drill hole with a lump of clay is a desirable method. Such practices should not be permitted. Properly confining an explosive is the cheapest and best way of using it so as to obtain the most efficient results.

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[a] Hall, Clarence, and Howell, S. P., Tests of permissible explosives: Bull. 66, Bureau of Mines, 1913, p. 20.

[b] Munroe, C. E., and Hall, Clarence, A primer on explosives for metal miners and quarrymen: Bull. 80, Bureau of Mines, 1915, p. 14.

The rate of burning of black blasting powder, size FF, when confined is approximately 1,540 feet per second.[b] The larger sizes as used in Illinois mines, principally F and C, have a still slower rate of burning, whereas the ordinary grades of permissible explosives detonate at a rate of about 7,500 feet per second when unconfined and at a higher rate when confined. Although a charge of black blasting powder in a drill hole may start to burn at a uniform rate when ignited, the rate of burning as the coal breaks and cracks form and the stemming is blown or shoved back may decrease before the charge is completely burned, as the powder tends to burn slower when the pressure is released. When a drill hole contains more black blasting powder than is necessary to break the coal free, the coal falls before all the powder has burned and the burning powder may ignite any gas liberated or any dust raised by the shot.

The same situation would arise if a hole was drilled to within a few inches of the face of another room or working, as in "holing through" a crosscut, or in slabbing pillar coal; the coal beyond the hole would offer little or no resistance to the blast. Often a poorly tamped hole results in a blown-out shot, and the flame of the burning powder may extend several feet from the mouth of the drill hole, and if inflammable dust or a small percentage of inflammable gas is present may initiate an explosion. Even when the shot appears to be correctly charged, its effect may be that of an overcharge in the presence of a slip, a fault, partings, or soft streaks in the coal, or of an undercharge in the presence of thick "sulphur" bands, with the result that the shot "throws" flame.

One of the fundamental distinctions between black blasting powder and permissible explosives is that black blasting powder by reason of its comparatively slow rate of burning exerts a wedging or heaving action, and as pointed out, any excess energy over that required to break down the coal may be expended on the air, possibly giving rise to a "windy" and therefore dangerous shot; whereas with a permissible explosive the action is more instantaneous and any excess energy of the explosive is expended on the coal with some shattering effect, but with the danger of a blown-out shot reduced to a minimum if the charge limit has not been exceeded. Because of the quick action of permissible explosives the amount used should be judged closely. The effect of the sudden release of pressure from the discharge of a permissible explosive is often observed on the stemming of a well-tamped shot. The clay plug will be compressed and hardened for several inches at the end that was nearest the explosive, but the rest of the plug will not be affected.

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[a] Snelling, Walter O., Hall, Clarence, The effect of stemming on the efficiency of explosives: T. P. 17, Bureau of Mines, 1912, p. 18.

[b] Hall, Clarence, Snelling, W. D., and Howell, S. P., Investigations of explosives used in coal mines with a chapter on the natural gas used at Pittsburgh, by G. A. Burrell, and an introduction by C. E. Munroe: Bull. 15, Bureau of Mines, 1911, p. 174.

However, the shattering effect of a permissible explosive in a well-directed and properly charged hole is confined to the coal in the immediate vicinity of the bore hole, and where the coal is undercut the amount of lump coal obtained is equal to that obtained with black blasting powder.

GROWTH IN THE USE OF PERMISSIBLE EXPLOSIVES IN ILLINOIS MINES.

The use of permissible explosives in Illinois, although covering only a comparatively recent time and restricted areas, nevertheless forms an interesting part of the coal-mining history of the State. Practically all early mining with explosives was done with black blasting powder; therefore miners were accustomed to its use, and even though acquainted with its dangers in a general way, they accepted these as a necessary hazard of the industry. After the explosions recorded in 1908, relief was sought. About this time, the Federal Government had through experiments brought to the attention of the mining public the fact not generally acknowledged that a blown-out shot of black blasting powder could cause a violent explosion with certain coal dusts without the presence of inflammable gas, and had advanced the possibilities of increased safety through the use of permissible explosives. Illinois coal operators began to investigate the merits of these short-flame explosives.

Perhaps the first tests in the State of permissible explosives were made at Dering No. 18 mine, West Frankfort, in 1909. The results were favorable. Shortly thereafter tests were made in various mines to determine the success or failure of permissible explosives under existing conditions.

At the United Coal Co.'s No. 1 mine, near Christopher, trial shots were made, and it was at this mine that later the tests for determining the prices at which permissible explosives should be supplied to the miners, under the working agreement between the operators and the miners, were conducted. At the first test five shots were arranged by the explosives manufacturer's representative, and it was then decided that the shots be fired by the shot firers in the usual manner. The officials of the coal company were present and waited to go below to observe the results. After the shots were fired, a telephone message came from below to the effect that the shots had not worked. This, of course, was disappointing, and the officials returned to headquarters thinking the results a failure. When the coal was loaded out the following day it was seen, however, that four of the five shots had done good work, and that the shot firers had arrived at their conclusions, not by a careful examination, but more from the detonations of the blasts, the report being somewhat sharper than the well-known resounding "boom" of black blasting powder. More tests were made with favorable results, and in a short time about 75 per cent of the miners in this mine were using permissible explosives, although some of the miners were still opposed to their use. Fortunately there were a number of miners who had used similar explosives in England, Wales,[a] and Belgium, and these were in a receptive mood, but to the majority of miners the use of these explosives was new.

Tests were also made at the Hart-Williams No. 1, Benton No. 1, Zeigler District No. 1, Christopher, Rend, Sesser, Zeigler, Dering No. 11, and Hanaford mines, and the use of permissible explosives was slowly introduced in these mines. In a number of mines the miners were given their choice of using either a permissible explosive or black blasting powder. In two mines this resulted in discontinuing the use of black blasting powder through popular choice. In another mine, where for a year permissible explosives were used in entries and black blasting powder in rooms, fires continued to occur regularly in rooms, but none in entries, and finally permissible explosives came to be used entirely. It was found that where the coal was properly undercut and "snubbed" the use of permissible explosives gave as good results as black blasting powder and little, if any, increase in the production of slack coal.

In 1910 two new mines were opened, the United Coal Co. No. 2 mine at Buckner and Old Ben No. 8 mine at West Frankfort. These mines, each with a daily capacity of 4,000 tons, have used only permissible explosives from the beginning.

By 1911 several mines were using permissible explosives exclusively. The West mine at West Frankfort, opened in 1912, began their use in 1913. Since 1913 all the mines opened in this district have used permissible explosives, including Old Ben No. 9, Christopher No. 2, and the Orient mine. Old Ben No. 9 mine was developed entirely with permissible explosives, producing more than 2,000 tons daily within 11 months from the time the coal was reached.

The Shoal Creek Coal Co., at its Panama mine, having had much trouble from local explosions and fires from use of black blasting powder, made a change to permissible explosives in the spring of 1913, a special test being conducted by a local powder commission.[a] In July, 1914, the Saline County Coal Co. made a change from black powder without shot firers to permissible explosives with shot firers at the Saline No. 3 mine, Harrisburg. The joint State powder commission [a] issued the following statement, June 5, 1914, in settlement of the powder question at this mine:[b]

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[a] In Great Britain those explosives which pass the required tests are called "permitted explosives."

> We, the joint State powder commission, who were called to review a local test held by the local powder commission at Saline County Coal Co.'s mine No. 3, find that the test was carried out as per contract. We, therefore, jointly recommend that when "permissible explosive" is installed in this mine in order to insure greater safety of the miners and to protect the company from mine fires the brand agreed upon by the local powder commission shall be the brand of permissible explosive used during the life of this contract, unless otherwise mutually agreed upon. Detonators will be delivered at the shaft bottom and permissible explosive be delivered as per State contract.

In January, 1916, the New mine of the Middle Fork Mining Co. was first operated on a commercial basis; permissible explosives are being used exclusively.

The Eldorado Coal & Mining Co. began to use permissible explosives in April, 1916, at the Seagraves mine, Eldorado, after a month's test. During a period of 14 months 5,372 fires were reported at this mine from black blasting powder, and the introduction of permissible explosives fills a long-felt need.

The results of the use of permissible explosives have been most favorable in these various mines. Data as to costs of explosive per ton, sizes of coal produced, and the advantages of permissible explosives are discussed later in this report.

DATA ON MINES USING PERMISSIBLE EXPLOSIVES.

Figure 2 shows the location of Illinois mines in which permissible explosives are now being used. Table 1 lists the companies using permissible explosives, gives data as to the location of mines, date of opening of mine, date of starting to use permissible explosives, material of construction of surface magazine, approximate average daily tonnage, depth of coal from surface, average thickness of coal, total number of employees, number of underground workers, total number of loaders, number of machine men, number and type of machines, depth of undercutting, number of shots per shift, number of shot firers, total daily wages of shot firers, size of cartridge used, method of firing, and average tonnage produced per 25-pound box of permissible explosive.

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[a] A joint State powder commission is provided for in the agreement between the Illinois coal operators and the miners for the settlement of any differences that can not be settled locally when a change of powder is to be made. The work of this commission includes settlement of disagreements relating to both black blasting powder and permissible explosives. Powder questions are first taken up locally by a local committee provided for under the same agreement and consisting of six representatives; three for the miners and three for the operators. If any disagreement can not be settled locally, it then goes before the joint powder commission for final decision. See pages 95-97 for the duties of this commission, agreement relative to settlement of powder questions, and procedure in making powder tests.

[b] Quarterly Bulletin, The Illinois Coal Operators Association, vol. 6, 1914, p. 113.

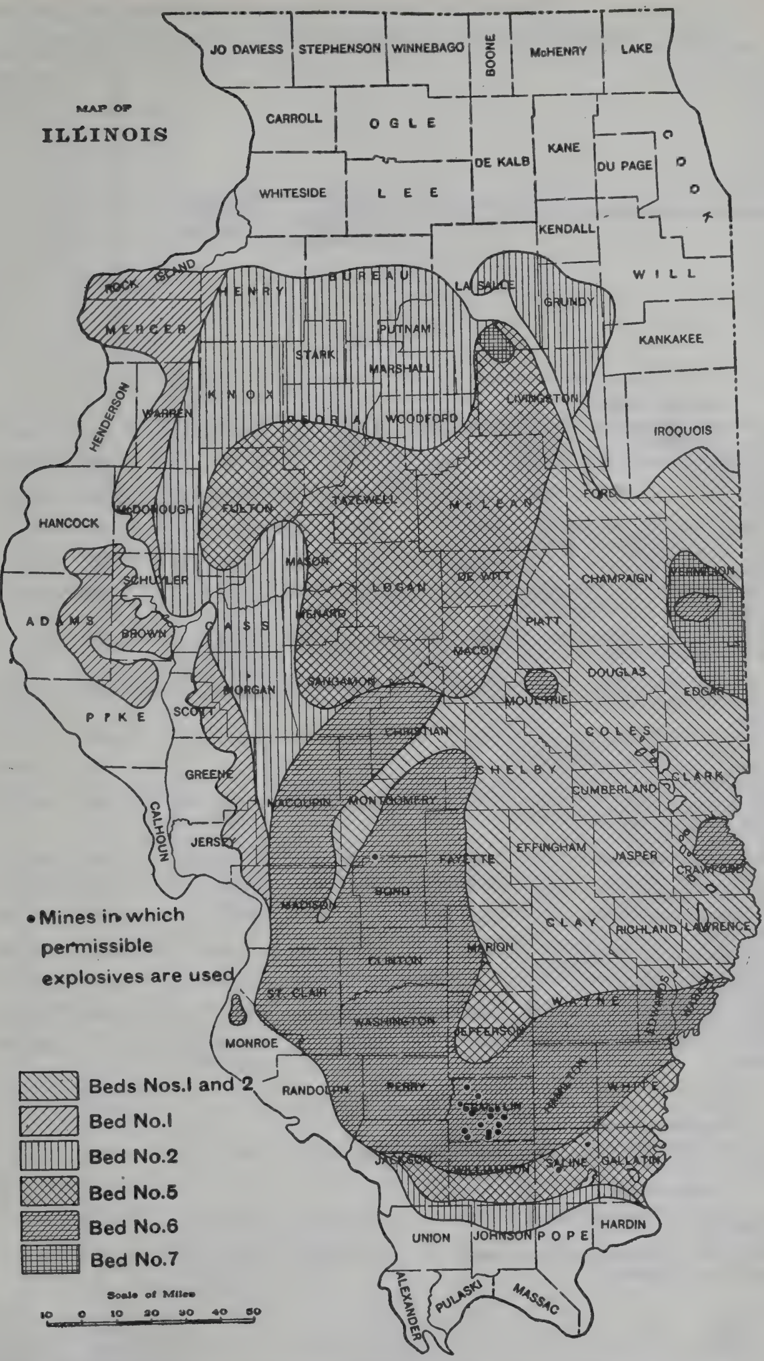

FIGURE 2.—Map of Illinois coal field, showing location of mines in which permissible explosives are used.

TABLE 1.—*Companies using permissible explosives exclusively*

[Coal No. 6 mined in Franklin and Montgomery Counties, coal No. 5 in Saline County.]

Operator, mine, and nearest town.	Date of opening of mine.	Date of beginning use of permissible explosives.	Material of construction of magazine.	Approximate average, daily tonnage.	Depth of coal [a] below surface.	Thickness of coal [a] bed.	
Franklin County.					*Feet.*	*Ft.*	*in.*
United Coal Mining Co., No. 1 mine, Christopher.	Sept., 1905	1909	Brick	3,000	500	*9	6
Hart-Williams Coal Co.,[b] No. 1 mine, Benton.	Sept., 1907	1909	do	2,400	630	9	6
Benton Coal Co.,[b] No. 1 mine, Benton.	1905	1909	do	2,500	634	9	6
Producers Coal Co., No. 18 mine (formerly Dering), West Frankfort.	1907	1910	do	1,300	510	10	
United Coal Mining Co., No. 2 mine, Buckner.	Aug., 1910	Aug., 1910	Hollow tile	4,000	472	*9	6
Producers Coal Co., No. 19 (formerly Dering No. 11) mine, West Frankfort.	1904	Sept., 1910	Brick	2,000	494	10	
Old Ben Coal Corporation, No. 8 mine, West Frankfort.	Sept. 1910	Sept., 1910	Wood, covered with tar paper.	4,400	460	*9	6
Bell & Zoller Mining Co., No. 1 (formerly Zeigler Coal Co.) mine, Zeigler.	1903	Dec., 1910	Cement	3,800	417	12	
Christopher Coal Mining Co., No. 1 (Old North) mine, Christopher, formerly operated by Zeigler District Collieries Co.	1908	1911	Brick	3,000	518	9	6
John A. Logan Coal Co., No. 1 mine, Logan (formerly Benton District Coal Co.), Hanaford.	Jan., 1909	July, 1911	Corrugated sheet-iron.	1,000	700	7	
Sesser Coal Co., Sesser mine	1906	Dec., 1911	Concrete	3,000	647	8	6
West Frankfort Coal Co., No. 1 mine, West Frankfort.	Sept., 1912	Aug., 1913	Concrete block.	1,700	443	9	6
W. P. Rend Collieries Co., No. 1 mine, Rend.	Jan., 1906	Sept., 1913	Brick	2,000	567	7	8
Christopher Coal Mining Co., No. 2 (New North) mine, Christopher.	Mar., 1914	Mar., 1914	do	3,500	593	*10	
Old Ben Coal Corporation, No. 9 mine, West Frankfort.	Oct., 1914	Oct., 1914	Concrete	3,800	468	10	
Chicago, Wilmington & Franklin Coal Co., No. 1 mine, Orient.	Dec., 1914	Dec., 1914	Brick	3,800	550	10	
Middle Fork Mining Co., New mine, Benton.	1915	1915	Wood (temporary).	(*d*)	600	*8	
Total				45,200			
Average				2,825	541	9	5
Montgomery County.							
Shoal Creek Coal Co., No. 1 mine, Panama.	Sept., 1905	May, 1913	Brick	2,500	381	7	
Saline County.							
Saline County Coal Co., No. 3 mine, Harrisburg.	1911	July, 1914	do	2,700	270	7	
Eldorado Coal & Mining Co., Seagraves mine, Eldorado.	1908	Apr., 1916	Wood and corrugated sheet iron.	2,000	450	4	10
Total				4,700			
Average				2,350	360	5	11
Grand total				52,400			
Grand average				2,750	515	8	11

[a] From annual coal report of Illinois, 1915, except those marked with an asterisk (*).

[b] Some black powder used in drawing pillars in 1911.

[c] Double shift.

and pertinent data as to methods. Data to Apr. 1, 1916.

[Coal No. 6 mined in Franklin and Montgomery Counties, coal No. 5 in Saline County.]

Number of employees.[a]		Total number of loaders.[a]	Machine men and helpers.[a]	Number of machines.	Type of machine.	Depth of undercutting.	Approximate number of shots per shift.	Number of shot firers.	Total daily wages of shot firers.	Size of cartridge used.	Method of firing.	Average tons produced per 25-pound box of permissible explosive per year, including rooms and entries.
Total.	Underground.											
						Feet.						
451	413	230	38	19	Breast	6	250	4	18.84	1¾ by 7 inches.	Fuse and No. 6 detonator.	140
558	518	395	36	18	do	7	200	4	18.84	1¾ by 6 inches.	do	130
570	510	325	38	19	do	6	260	4	18.84	do	do	145
258	238	150	30	15	do	6	120	2	9.42	do	do	126
620	576	342	52	26	do	6	320	4	18.84	1¾ by 7 inches.	do	130
300	275	146	66	33	Air puncher.	4	165	3	14.13	1¾ by 6 inches.	do	125
548	471	350	54	27	Breast	6	320	6	28.26	1¾ by 7 inches.	Battery and No. 6 electric detonator.	164
680	617	394	57	29	do	6	300	6	28.26	1¾ by 6 inches.	Fuse and No. 6 detonator.	144
470	419	247	46	23	do	6	260	4	18.84	1¾ by 6 inches, 1¾ by 7 inches.	do	170
167	141	100	20	10	do	5	110	2	9.42	1¾ by 6 inches.	do	128
483	463	325	32	20 7	Air puncher, shortwall.	5.5 6	250	4	18.84	do	do	202
287	262	185	26	13	Breast	6	130	2	9.42	do	do	138
434	394	256	41	21	do	5	240	4	18.84	do	do	120
450	408	289	38	19	do	7	250	4	18.84	do	do	176
445	400	260	32	16	do	7	240	4	18.84	1¾ by 7 inches.	Battery and No. 6 electric detonator.	150
488	428	300	30	15	Shortwall	7	225	4	18.84	1¾ by 6 inches.	Fuse and No. 6 detonator.	140
*110	*95	*66	*12	6	Breast	6	Just developing.				do	
7,319	6,628	4,360	648	336			3,640	61	287.31			
430	390	256	38	20		6.3	228	4	18.00			145
594	546	335	44	22	Breast	6	300	4	18.84	1¾ by 7 inches.	Fuse and No. 6 detonator.	107
425	384	224	36	c 9	Breast	6	225	4	20.06	1¾ by 6 inches.	do	215
311	298	*205	24	12	4 shortwall 8 breast	6.5 6	220	4	19.76	do	do	(e)
736	682	429	60	21			445	8	39.82			
368	341	215	30	11		6	223	4	19.91			215
8,649	7,856	5,124	752	379			4,385	73	345.97			
432	392	256	38	19		6+	231	4	18.21			147

[d] Producing 600 tons daily; just being developed.
[e] First month's production, 250 to 290 tons in rooms, 150 tons in entries.

In the mines listed in Table 1, permissible explosives are now used exclusively. As noted in the table, the total average daily tonnage of the 19 producing mines is 52,400 tons, or 2,750 tons per mine. The total number of employees is 8,649, or more than 11.44 per cent of the total number, 75,607, employed in the mines of the State.[a]

Of the mines listed, those in which permissible explosives have been used exclusively from the start are: Mine No. 2, United Coal Mining Co., Buckner; Mine No. 8, Old Ben Mining Corporation, West Frankfort; Mine No. 9, Old Ben Mining Corporation, West Frankfort; Mine No. 2, Christopher Coal Mining Co., Christopher; Mine No. 1, Chicago, Wilmington & Franklin Coal Mining Co., Orient; New mine, Middle Fork Mining Co., Benton.

Tests have been made at the No. 6 mine of the Saline County Coal Co., Grayson, in the No. 5 seam, and permissible explosives were used in all entries on trial during the month of March, 1915. Good results were obtained and the tests showed that permissible explosives would be cheaper for the miner. The company is anxious to introduce permissible explosives at this mine on account of the numerous fires resulting from the use of black powder. Since the company took over this property in 1914, solid shooting has been supplanted by machine mining. Although past experience has shown the danger of using black blasting powder, the acceptance of permissible explosives by the miners has been delayed, and the matter has been referred to the joint State powder commission.

In addition to the mines listed, permissible explosives have been used to some extent in other mines in Illinois for special work. Among these, the Wasson Coal Co. used some in its new slope mine No. 2, at Carriers Mills, in 1914, in development work when the coal was first reached. In 1915, the Canton Coal Co., Canton, used a small amount of these explosives in rock work; the Marion County Coal Co., Centralia, used about 200 pounds in a test in blasting coal, and the New Enterprise Coal Co., used 1,725 pounds for shooting wet holes at their stripping operation at Marion, Ill. Permissible explosives have been used in some entry work at No. 1 mine, Royalton, but have not come into general use throughout the mine. Of the 20 mines in Franklin County, all use permissible explosives exclusively, except two at Royalton, and one at Freeman.

COST OF PERMISSIBLE EXPLOSIVES TO OPERATOR AND TO MINER.

It has been the custom for many years in Illinois mines for the operators to sell the black blasting powder to the miners, at a price that has been specified in the jointly made annual or biennial contracts between operators and miners.

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[a] Annual coal report of Illinois for 1915, State Mining Board, 1916, p. 2.

The selling price of permissible explosives during the introductory period ranged from $3 to $3.50 per 25-pound box. In some instances, so it was claimed, this increased the cost to the miner about 1 cent per ton of coal, whereas in other instances there was no marked difference compared with black blasting powder selling at $1.75 per 25-pound keg, because the production with permissible explosives was found to be approximately in the proportion of 2 tons to 1 with black blasting powder. As soon as the success of permissible explosives was assured the miners raised the issue as to their rights in the establishment of the price of the explosive to come under the operation of their contract. In making his report to a State-wide meeting of the miners Groce Lawrence made special mention of the introduction of permissible explosives during the fall and winter of 1909 and 1910, as follows:[a]

> The United Coal Mining Co. at Christopher was experimenting with a permissible explosive. At Sesser, the Franklin County Collieries Co. was making a test of another permissible explosive, and at Rend City the Rend Coal Co. was experimenting with some other brand.
>
> Board Member Smith and myself had this permissible explosive question up with these operators on several different occasions prior to April 1, 1910, but nothing definite was done other than to inform them and the miners in their employ that if they wished to change from the powder then in use to this new explosive they would have to file a petition and handle the proposition in its entirety as provided for in the eighth clause of the State agreement.[b]
>
> On several occasions the miners of Franklin County spoke to me about buying and using these new explosives. I always took the time and pains to explain to them what their rights were under the contract, and advised them not to buy any of it until the question had been definitely settled and a price agreed upon. * * *
>
> Immediately after the settlement was made last September a petition was filed by the miners working at the No. 1 mine of the United Coal Mining Co. at Christopher to have the [joint State] powder commission make a test at that mine to determine what the relative cost of permissible explosive would be as compared to black powder at $1.75 per [25-pound] keg.
>
> As soon thereafter as arrangements could be made, or on September 28, 1910, the joint powder commission met at Christopher for the purpose of making a test at the No. 1 mine of the United Coal Mining Co. They devoted about 30 days to the making of this test and in trying to reach an agreement as to the relative cost.

In this same report is related the difficulty attending the agreement as to the relative price, the miners contending for a price of $2.45 per 25-pound box, whereas the operators, on account of the cost of permissible explosives and certain other facts as to relative productive values, endeavored to obtain a price more satisfactory to them.

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[a] Twenty-second Annual Convention of District No. 12, United Mine Workers of America, 1911, pp. 33, 34.

[b] See p. 96.

A temporary agreement was made as follows:

TEMPORARY AGREEMENT OF JOINT POWDER COMMISSION, OCTOBER 12, 1910.

Meeting of the joint powder commission,[a] St. Louis, Mo., for the purpose of taking up and considering the data and all matters pertaining to the test made with (name of permissible explosive) and black blasting powder at the United Coal Mining Co.'s No. 1 mine, Christopher, Ill. The commission agree to use permissible explosive in the above-mentioned mine, and based on a temporary price of $2.80 a box of 25 pounds of explosive to be charged the miners until a more rigid and thorough investigation and test be made, and which must be made within 30 days from date, and should any charge be made other than $2.80 per box after a permanent price has been settled upon by the commission that operator and miners shall be paid said difference as the case may be.

The commission was agreed that the use of permissible explosives would be for the benefit and protection of life and property. The matter was finally adjusted as stated by C. M. Moderwell,[b] president of the Illinois Coal Operators' Association:

The temporary agreement of the joint State powder commission made October 12, 1910, fixed a price of $2.80 per box on the permissible explosive which was then being used at the United Coal Mining Co.'s No. 1 mine at Christopher. It was decided by the mining company that the use of a permissible explosive was absolutely necessary at this mine, but the attempt to introduce it caused a good deal of trouble, and while the temporary agreement above referred to was in effect for some time, on January 17, 1911, the joint powder commission reported a final disagreement and referred it to the joint executive board of the miners and operators. Early in March, 1911, the miners' officials issued orders to the miners working in the mine above referred to, as well as those in other mines in that district, not to pay more than $2.45 per 25-pound box of carbonite or other permissible explosive after April 1. A special committee representing Franklin County met the miners' board in Chicago on April 7, 1911, and D. W. Buchanan, for the operators, and John H. Walker, for the miners, were appointed to investigate the prices charged for permissible explosives in the East. They reported at a meeting of the joint executive board held in Chicago May 10 and 11, and the following was finally agreed upon:

In case any operator desires to use a permissible explosive, a price of $2.45 per box for (names of two brands of permissible explosives) is hereby established during the remainder of the present contract year, it being understood that the efficiency of the "permissible" used is to be maintained equal to the same standard established in the joint test upon which the above price was based. Any dispute arising out of this decision as to the efficiency of the "permissible" furnished shall be taken up the same as any other powder dispute under the contract.

The price of $2.45 per 25-pound box has since been made a part of the contract and is operative at the present time. Although this allows a small margin of profit compared with handling black blasting powder, there has been no dissatisfaction. However, in 1915 and 1916, owing to the European war, manufacturers' prices of permissible explosives were raised, so that some coal companies were selling permissible explosives at a loss of from 50 to 75 cents per 25-pound box. Some discussion was given the question of equalizing the losses due to the increased cost of explosives during the joint convention in the establishment of the new wage scale, April, 1916, but no decision was reached, and the original contract is in force. Explosive is delivered to the miner at his working place at $2.45 per 25-pound box.

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[a] See pp. 96–97 for duties of commission.

[b] By correspondence.

KINDS OF PERMISSIBLE EXPLOSIVES USED IN ILLINOIS.

There are at present four powder companies selling permissible explosives in Illinois—the Ætna Explosives Co. (Inc.), New York, N. Y.; the Burton Powder Co., Pittsburgh, Pa.; E. I. du Pont de Nemours & Co., Wilmington, Del.; and the Illinois Powder Manufacturing Co., St. Louis, Mo. The explosives and their characteristics are given in Table 2 following. As noted, the nitroglycerin class of explosives is used almost exclusively in Illinois.

TABLE 2.—*Permissible explosives used in Illinois and their characteristics.*[a]

Brand and manufacturer.	Size of cartridge, inches.	Rate of detonation,[b] feet per second in 1¼-inch cartridge.	Pressure,[c] pounds per square inch.	U. D. C.,[d] grams.	Compression, small lead block test,[e] millimeters.[f]	Expansion, trauzl lead block test,[g] cubic inches.
Ætna Explosives Co. (Inc.):						
Ætna coal powder B	1¾ by 6	9,870	[h] 84,083	301	13.8	11.90
Ætna coal powder C	1¾ by 6	7,010	60,140	344	10.7	8.78
Burton Powder Co.:						
Mine-ite B	1¾ by 7	9,540	62,030	340	10.5	9.70
E. I. du Pont de Nemours & Co.:						
Carbonite No. 3	1¾ by 7	8,710	[h] 70,742	325	10.8	9.52
Carbonite No. 5	1¾ by 7	10,140	70,270	304	11.7	9.52
Carbonite No. 6	1¾ by 7	7,490	62,470	345	8.8	7.38
Monobel No. 5 [i]	1¾ by 6	6,760	106,100	267	12.2	8.97
Illinois Powder Manufacturing Co.:						
Black Diamond No. 3-A	1¾ by 6	11,160	82,590	294	14.5	10.13
Black Diamond No. 6-L. F.	1¾ by 6	9,630	88,770	306	13.2	9.76
Average		8,920	76,355	314	11.8	9.52

[a] See Bulletin 66, Tests of permissible explosives, by Clarence Hall and Spencer P. Howell, for significance of terms and detailed results of tests.

[b] Rate of explosion, or rate at which detonation travels through a given length of explosive. Rate of detonation of 1¾-inch diameter cartridges greater, but not yet determined by experiment.

[c] Maximum theoretical pressure exerted on explosion, in paper wrapper except where noted.

[d] Unit deflective charge. Number of grams required to give same propulsive effect as 227 grams of 40 per cent standard dynamite.

[e] A certain measure of relative compressive effect of explosive, with charge unconfined.

[f] 25.4 millimeters=1 inch.

[g] A certain measure of comparative disruptive effect of explosive.

[h] In tinfoil wrapper.

[i] All explosives are Class 4, nitroglycerin, excepting Monobel No. 5, which is Class 1*a*, ammonium nitrate, containing nitroglycerin.

NOTE.—The weight per stick of explosive varies, there being 40 to 53 sticks per 25-pound box of explosive.

GENERAL INCREASE IN THE USE OF PERMISSIBLE EXPLOSIVES IN ILLINOIS AND THROUGHOUT THE UNITED STATES.

The following figures from the annual coal reports of Illinois show the marked increase in the quantity of permissible explosives used in coal mining in Illinois during the fiscal years ended June 30, 1911, to 1915: 1911, 243,099 pounds; 1912, 328,075 pounds; 1913, 603,420 pounds; 1914, 930,596 pounds; 1915, 1,342,334 pounds.[a] This increase is also shown graphically in figure 1.

The rapid increase in the quantities of short-flame[b] explosives sold for use in coal mining in the United States from 1901 to 1914 is shown by the table following:

Quantities of short-flame explosives sold for use in coal mines of the United States, 1901–1914.[a]

Year.	Quantity sold.	Year.	Quantity sold.
	Pounds.		*Pounds.*
1901		1908	2,108,610
1902	11,300	1909	8,942,857
1903	288,661	1910	11,820,836
1904	608,270	1911	13,428,239
1905	1,031,300	1912	18,150,618
1906	1,533,575	1913	21,804,285
1907	2,095,244	1914	19,593,892

[a] Fay, A. H., Production of explosives in the United States in 1914; Tech. Paper 107, Bureau of Mines, 1915, p. 13.

In 1902 only 11,300 pounds of short-flame[b] explosives was used in coal mining; in 1913 the amount used was 21,804,285 pounds. There was a decrease of about 10 per cent in the amount used in 1914 as compared with 1913. This decrease is in harmony with the smaller production of coal during 1914.

The quantity of permissible explosives used for mining coal in the various coal fields of the United States, 1910 to 1914, is as follows:

Quantities of permissible explosives used in different coal fields in the United States, 1910–1914.[a]

Coal fields and regions.	1910	1911	1912	1913	1914
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
1. Pennsylvania anthracite field	1,486,100	1,917,412	2,177,172	3,294,225	4,380,635
2. Northern Appalachian region[b]	5,967,216	6,350,272	9,190,025	9,744,810	7,966,464
3. Southern Appalachian region	3,188,785	3,377,268	3,995,485	4,481,975	3,510,013
4. Eastern interior field	165,975	337,012	751,005	2,058,075	1,364,450
5. Western interior field	196,560	255,050	440,825	377,625	411,937
6. Rocky Mountain region	808,200	1,177,075	1,473,129	1,634,575	1,796,750
7. Pacific coast region	8,000	14,150	122,977	213,000	163,643
Total	11,820,836	13,428,239	18,150,618	21,804,285	19,593,892

[a] Fay, A. H., Production of explosives in the United States in 1914, Tech. Paper 107, Bureau of Mines, 1915, p. 13.

[b] Not including Pennsylvania anthracite field.

STATE LAWS REGULATING THE CHARACTER OF PERMISSIBLE EXPLOSIVES.

The transportation and storage of explosives, the preparation of shots, and methods pursued in the firing of shots are governed in general by the State mining law and the working agreement of the operators and miners.[a]

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[a] Includes about 8,000 pounds of dynamite erroneously reported as permissible explosives.

[b] The name "permissible explosives" was adopted by the Bureau of Mines in 1908.

The Illinois mining law requires that all permissible explosives for use in blasting coal in the State shall conform to the following specifications:

> (*a*) All permissible explosives offered for sale in the State of Illinois shall have printed on each cartridge and individual package the name of the manufacturer, the registered trade-mark, brand, grade, and a statement that it conforms in strength to that grade and brand established by the United States Bureau of Mines;
>
> (*b*) Each shipping case shall have marked on it the total weight of explosives contained therein, and the average weight, length, and diameter of each stick contained therein;
>
> (*c*) Each shipping case containing permissible explosives shall be marked "Permissible explosives."
>
> (*d*) Each ingredient of a permissible explosive shall not vary more than the permitted variation established by the United States Bureau of Mines.[b]

STORAGE AND HANDLING OF EXPLOSIVES.

POWDER MAGAZINES.

Plate III shows typical powder magazines at mines in Franklin County. The construction includes corrugated iron, wood covered with tarred paper, hollow tile, concrete block, brick, and cement. The capacity of the magazines ranges from 15 to 50 tons of explosive. Magazines for the storage of detonators and fuse are constructed practically of the same material as the powder magazines. The Illinois State mining law stipulates the location and construction of magazines as follows:

> All explosive materials shall be stored in a fireproof magazine located on the surface not less than 500 feet from all other buildings in connection with the mine, and such magazine shall be so placed as not to jeopardize the free and safe exit of men from the mine in case of an explosion at the magazine.[c]
>
> Permissible explosives shall be stored in magazines constructed in accordance with plans that shall be approved by the State mine inspector of the district in which the mine is located.
>
> Every magazine shall be provided with a wooden floor, which shall be kept free from grit and dirt. If more than one kind of explosive is kept in the same magazine, the magazine shall be divided into rooms by partitions. The different kinds of explosives shall be kept in different rooms, but no detonators, or blasting caps, or any device containing fulminating composition shall be kept in the same magazine with any explosive. All detonators, blasting caps, or any device containing fulminating composition shall be kept separate in a safe and dry receptacle apart from any other explosive.

The preservation of permissible explosives in a high state of efficiency demands that the magazine be kept well ventilated, especially during the summer. At two mines special thaw houses are used during the winter months for thawing and storing each day's supply of explosives. The thaw houses are heated by exhaust steam at low pressure. Usually, however, the mine temperature, which normally in the interior of Illinois coal mines is 60° to 70° F, is depended upon to thaw the explosive and keep it at a proper temperature for use.

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[a] See Appendix, p. 97.

[b] See p. 99 for "Tolerances for permissible explosives," promulgated by the Bureau of Mines, July 1, 1915, from Bulletin 96, The analysis of permissible explosives, by C. G. Storm, 1916, pp. 80-81.

[c] Coal-mining laws of Illinois: Section 11 (b).

The Bureau of Mines has made a special study of the storage and handling of explosives, and attention is called to the bureau's Technical Paper 18,[a] which deals with the problems of selection of site and specifications of construction of magazine. The type recommended by the bureau is shown in Plate IV, *A*, and details of construction in figure 3. Such information may serve as a guide to future construction of magazines at Illinois mines.

The following brief comment is taken from Technical Paper 18:[b]

BUREAU OF MINES MAGAZINE.

As a result of experiments and of information furnished by the manufacturers of explosives, a cement-mortar magazine (Pl. IV, *A*, and fig. 3) has been erected by the Bureau of Mines. The magazine has a capacity of 20,000 to 30,000 pounds of explosives, and was built at a cost of $400. The outside dimensions are 10 to 14 feet.

The salient features of the magazine are the cement-mortar walls, sliding door, and roof. The cement mortar is 6 inches thick in all walls and 3 inches thick in the roof and the door. The door is secured by two substantial locks. No metal of any kind is exposed on the inside of the magazine. The ventilators above the floor are arranged to prevent the entrance of bullets or firebrands.

The means provided for ventilation have been found to be adequate, and, accordingly, the storage conditions are favorable for keeping the explosives from deteriorating. The cement-mortar construction is effective in resisting the penetration of rifle bullets, and because of its friable nature offers an additional advantage for the reason that, in the event of an explosion in or near the magazine, large masses of material will not be projected over the surrounding country. The galvanized-iron covering is fire resisting; it also serves as an excellent medium for protection against lightning, as the four corners of the building are properly grounded with metal rods.

In order that the details of construction may be thoroughly understood, the following bill of materials is presented. The concrete of the foundation consists of one part cement, three parts sand, and five parts gravel. The cement-mortar in the walls, door, and roof consists of one part cement to six parts coarse sand

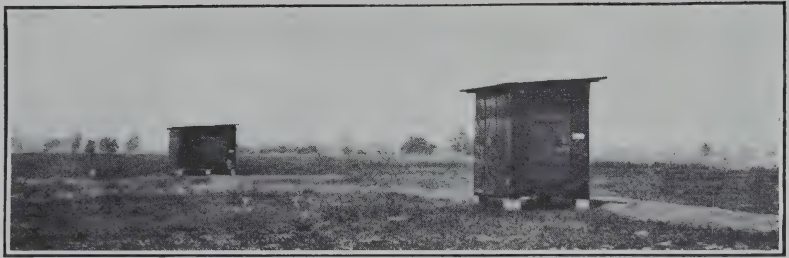
BILL OF MATERIALS.

Lumber:
- 1 piece of yellow pine, 2 inches by 6 inches by 18 feet.
- 1 piece of yellow pine, 6 inches by 8 inches by 14 feet.
- 11 pieces of yellow pine, 2 inches by 10 inches by 10 feet.
- 2 pieces of yellow pine, 1 inch by 3 inches by 12 feet.
- 4 pieces of yellow pine, 2 inches by 10 inches by 10 feet.
- 8 pieces of yellow pine, 2 inches by 6 inches by 14 feet.
- 9 pieces of yellow pine, 2 inches by 8 inches by 10 feet.
- 6 pieces of yellow pine, 2 inches by 4 inches by 7 feet.
- 6 pieces of yellow pine, 2 inches by 4 inches by 8 feet.
- 2 pieces of yellow pine, 4 inches by 4 inches by 7 feet.

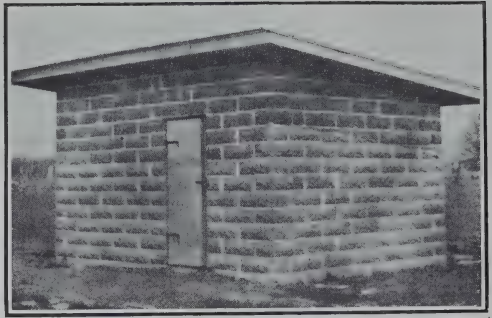
---

[a] Hall, Clarence, and Howell, S. P., Magazines and thaw houses for explosives: Technical Paper 18, Bureau of Mines, 1912, 34 pp.

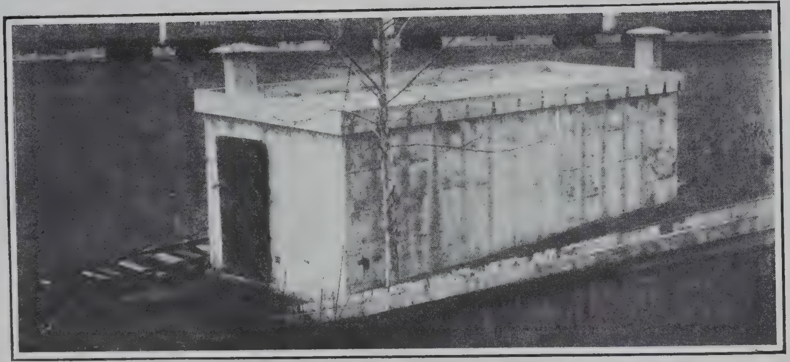
[b] Hall, Clarence, and Howell, S. P., work quoted pp. 18, 19, 25, 26.



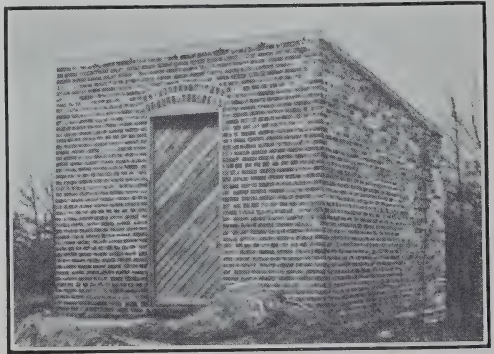
A. WOODEN POWDER MAGAZINES TYPICAL OF THOSE IN SOUTHERN ILLINOIS.



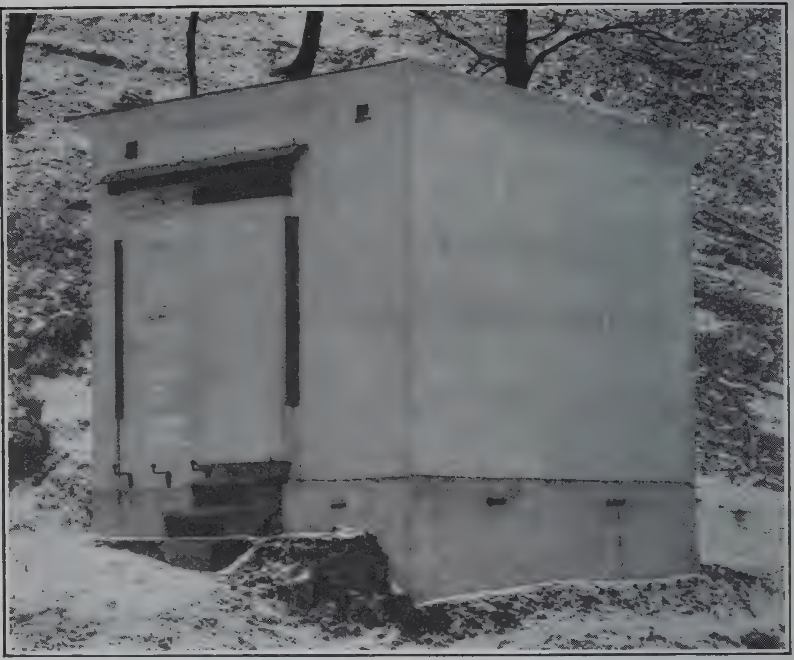
C. CONCRETE-BLOCK POWDER MAGAZINE AT AN ILLINOIS MINE.



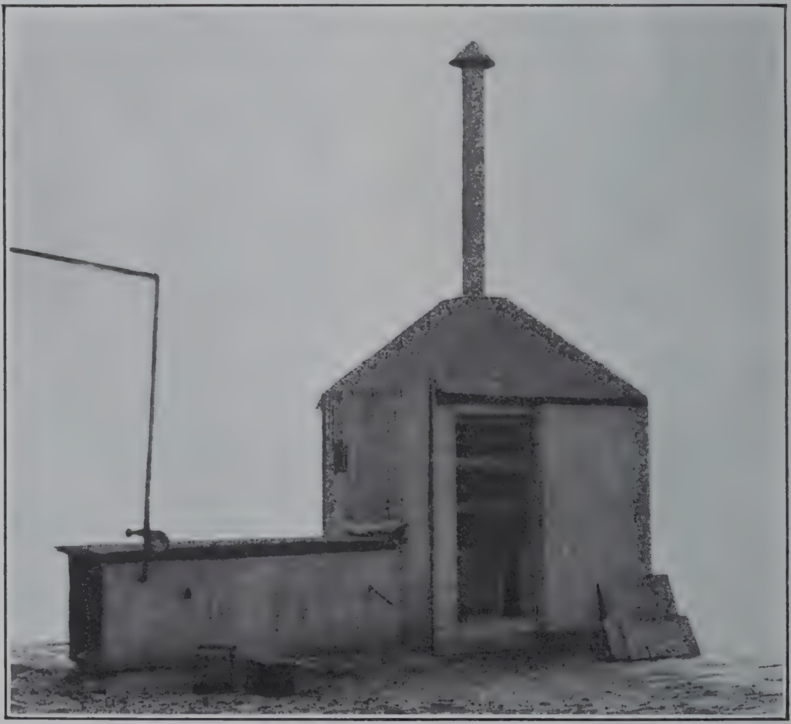
B. POURED-CONCRETE MAGAZINE AT AN ILLINOIS MINE.



D. BRICK POWDER MAGAZINE AT AN ILLINOIS MINE.



A. BUREAU OF MINES CEMENT-MORTAR MAGAZINE.



B. BUREAU OF MINES CEMENT-MORTAR THAW HOUSE.

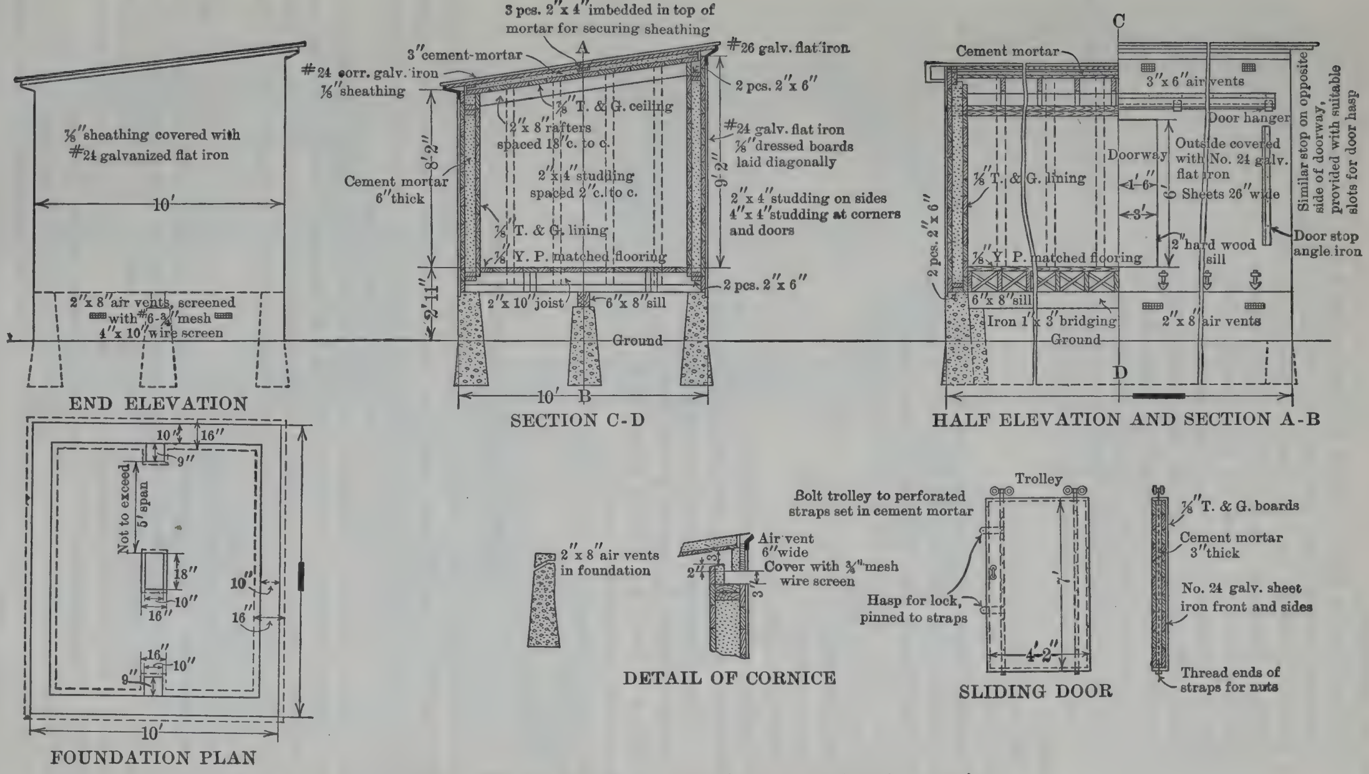

END ELEVATION
⅞" sheathing covered with #24 galvanized flat iron
10'
2"x 8" air vents, screened with #6-¾" mesh 4"x 10" wire screen
SECTION C-D
3 pcs. 2"x 4" imbedded in top of mortar for securing sheathing
3" cement-mortar
A
#26 galv. flat iron
#24 corr. galv. iron
⅞" sheathing
2 pcs. 2"x 6"
⅞" T. & G. ceiling
2"x 8" rafters spaced 18" c. to c.
8'-2"
9'-2"
#24 galv. flat iron
⅞" dressed boards laid diagonally
Cement mortar 6" thick
2"x 4" studding spaced 2' c. to c.
2"x 4" studding on sides
4"x 4" studding at corners and doors
⅞" T. & G. lining
⅞" Y. P. matched flooring
2 pcs. 2"x 6"
2'-11"
2"x 10" joist
6"x 8" sill
Ground
10'
B
HALF ELEVATION AND SECTION A-B
C
Cement mortar
3"x 6" air vents
Door hanger
Similar stop on opposite side of doorway, provided with suitable slots for door hasp
Doorway
Outside covered with No. 24 galv. flat iron
Sheets 26" wide
⅞" T. & G. lining
1'-6"
6'
3'
2 pcs. 2"x 6"
2" hard wood sill
Door stop angle iron
⅞" Y. P. matched flooring
6"x 8" sill
Iron 1"x 3" bridging
2"x 8" air vents
Ground
D
FOUNDATION PLAN
10"
16"
9"
Not to exceed 5' span
18"
10"
16"
10"
16"
16"
10"
9"
10'
DETAIL OF CORNICE
2"x 8" air vents in foundation
Air vent 6" wide
Cover with ¾" mesh wire screen
3"
2"
3"
SLIDING DOOR
Trolley
Bolt trolley to perforated straps set in cement mortar
Hasp for lock, pinned to straps
7'
4'-2"
⅞" T. & G. boards
Cement mortar 3" thick
No. 24 galv. sheet iron front and sides
Thread ends of straps for nuts

FIGURE 3.—Plan and sections of Bureau of Mines cement-mortar magazine.

Lumber—Continued.
2 pieces of yellow pine, 4 inches by 4 inches by 8 feet.
24 pieces of yellow pine, 2 inches by 4 inches by 9 feet.
3 pieces of yellow pine, 2 inches by 4 inches by 14 feet.
9 pieces of hemlock, 1 inch by 10 inches by 10 feet.
8 pieces of hemlock, 1 inch by 10 inches by 12 feet.
15 pieces of hemlock, 1 inch by 10 inches by 14 feet.
28 pieces of hemlock, 1 inch by 10 inches by 16 feet.
400 feet of lumber for framework of foundation.
48 board feet of 16-foot No. 2 white-pine flooring.
856 board feet of No. 2 yellow-pine flooring, consisting of 19 bundles 16 feet long, 1 bundle 14 feet long, and 11 bundles 10 feet long.
Hardware:
100 pounds of 8d. wire nails.
40 pounds of 20d. wire nails.
4 pieces of iron, $\frac{3}{8}$ inch by $1\frac{1}{4}$ inches by 7 feet.
2 pieces of iron, $\frac{3}{8}$ inch by $1\frac{1}{4}$ inches by 18 inches.
2 pieces of angle iron, 3 inches by 5 feet long.
2 pairs of No. 130 Coburn trolley hangers.
8 feet of No. 4 track.
2 end brackets.
1 center bracket.
1 heavy iron door handle.
4 brackets with hardwood rollers.
500 square feet of No. 26 gage galvanized flat iron.
150 square feet of galvanized corrugated iron.
2 pieces of 5-inch by 8-inch, $\frac{3}{4}$-inch mesh, No. 6 wire screen.
8 pieces of 4-inch by 10-inch, $\frac{3}{4}$-inch mesh, No. 6 wire screen.
Cement, sand, and gravel:
80 bags of cement.
200 bushels of sand.
150 bushels of gravel.

CONSTRUCTION OF THAW HOUSES.

What has been said of the construction of magazines applies equally to the designing of thaw houses. In addition to protecting thaw houses from dangers from without, the increased sensitiveness of explosives within the thaw house involves another danger, due to the high temperatures that must be maintained.

Thaw houses are usually situated so as to be convenient to the shaft, pit mouth, or place where the explosives are being used, and consequently should be constructed of material that would not be projected in large pieces should an accidental explosion occur. It is also essential that thaw houses be bullet proof, and protected from lightning, unlawful entry, and fire.

In constructing thaw houses some source of heat that can be kept within safe limits must be introduced. Low-pressure steam is usually available and when used at pressures not exceeding 3 pounds, in a manner herein described, it has been found to be effective and one of the safest means of thawing explosives. The temperature of the air entering a compartment should never exceed 130° F., and a lower temperature is desirable if a temperature of 90° F. can be maintained within the thaw house.

The cement-mortar thaw house (Pl. IV, *B*, and figs. 4 and 5) recently built by the Bureau of Mines for thawing large quantities of explosives has a capacity of 500 pounds and cost complete $200. It was erected after a consideration of the various details involved, is not of prohibitive cost, and offers the following advantages:

The cement-mortar walls, roof, and doors protect the explosives from bullets; the cement-mortar and galvanized-iron covering are fire resisting, and the latter furnishes

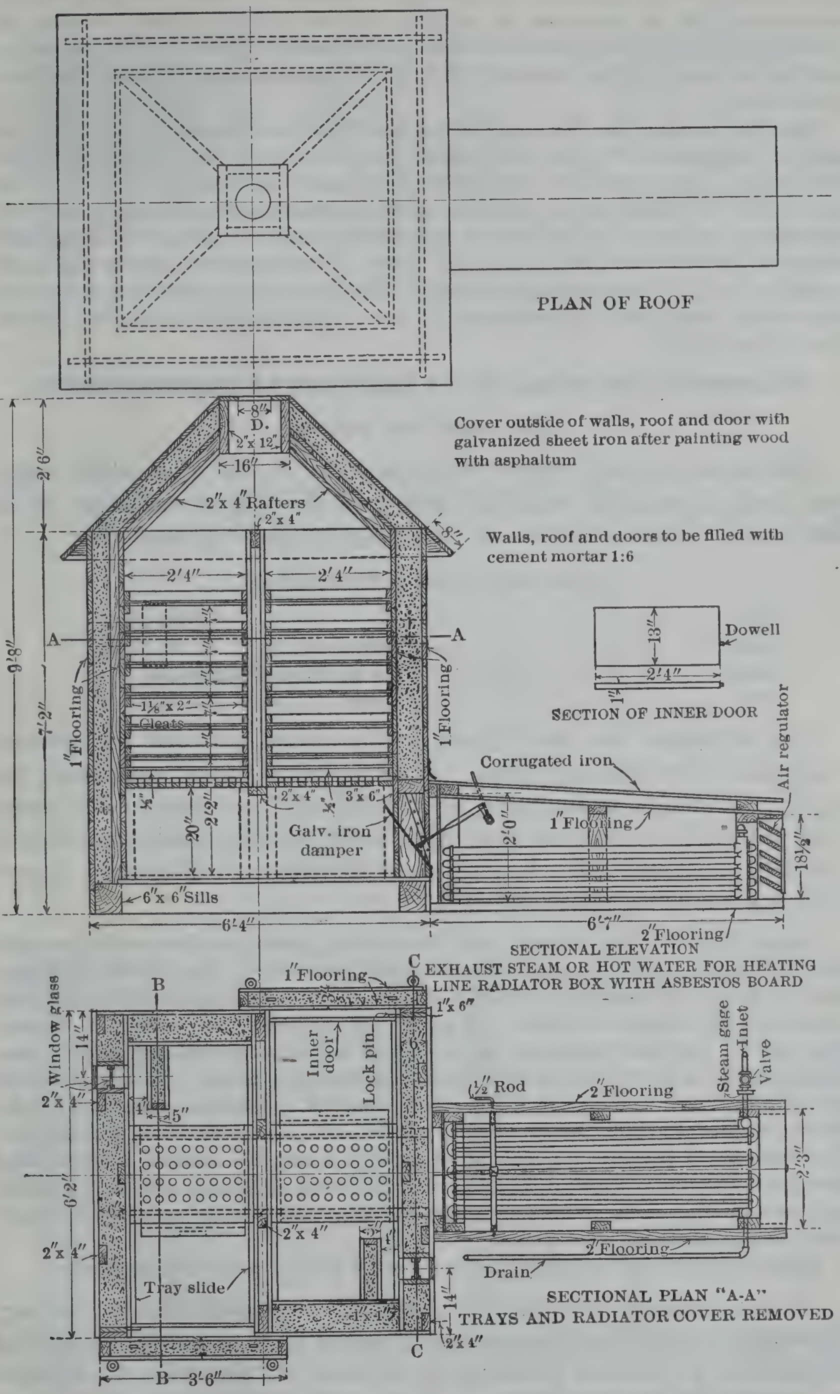


FIGURE 4.—Roof plan and sections of Bureau of Mines cement-mortar thaw house.

a good conductor for lightning; the building is substantial; entrance is difficult and is unnecessary, for the trays can be entirely removed without anyone entering the house (see Pl. IV, *B*); all parts of the house are accessible for cleaning; the explosives can be distributed in thin layers in the trays; the thermometers are easily read from without.

The thaw house of the Bureau of Mines also offers the following advantages in regard to temperature: No high temperature from artificial sources of heat obtains in the vicinity of the thaw house; the low-pressure steam, hot-water, or electric coils are not in the thaw house proper but in a separate compartment at its side, and hence particles of explosives can not come in contact with them; the explosives are not subjected to the evil effects of free steam or water; the temperature is surely and easily controlled with little attention; the entrance of cool air or the escape of heat from the thaw house is reduced to a minimum; the stack makes possible the positive circulation of heated air.

DELIVERY AND STORAGE OF EXPLOSIVES UNDERGROUND.

DELIVERY TO MINER.

The miner usually orders his explosives at the mine office, signing a slip, a copy of which is pasted on the box of explosive to be delivered. The inscription on one of these slips is given below:

Order slip for permissible explosives.

Side...........................	*Mine No*......
Entry No......................	Deliver to..........Ck. No......
Room...........................	**One Box Permissible Explosive**
Date...........................	Name...........................

The explosive for the following day is taken from the powder magazine after quitting time. After the shots have been fired, the supply ordered is taken below and distributed to various room necks and entries by a powder man with mule and car while the electric current is turned off. Explosive is delivered in 25-pound boxes. The State law [a] reads as follows:

> *Amount of powder kept in mine.*—(*a*) No blasting powder or other explosives shall be stored in any coal mine, and no workmen shall have at any time in the mine more than 35 pounds of black powder nor more than 25 pounds of permissible explosives, nor more than 3 pounds of other high explosives, provided that nothing in this section shall be construed to prevent the operator of any mine from taking into the mine, when miners are not therein, and in electrically equipped mines, while the current is turned off on roadways through which it is transported, a sufficient quantity of powder for the reasonable requirements of such mine for the next succeeding working day. The delivery of powder into coal mines shall be during the interval after the shot firers have come out of the mine and prior to the entry of the day shift into the mine in the morning; but in the interim before such powder is delivered to the men, it shall be kept in a closed receptacle.
>
> Explosives shall not be carried in the same car with tools or other materials.

As the working agreement [b] places the responsibility of delivery of explosives on the operator, some mines have a system of storing explosives at various partings or sections in the mine in wooden

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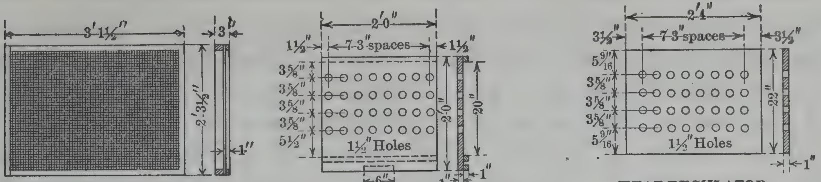
[a] Coal-mining laws of Illinois, sec. 19.

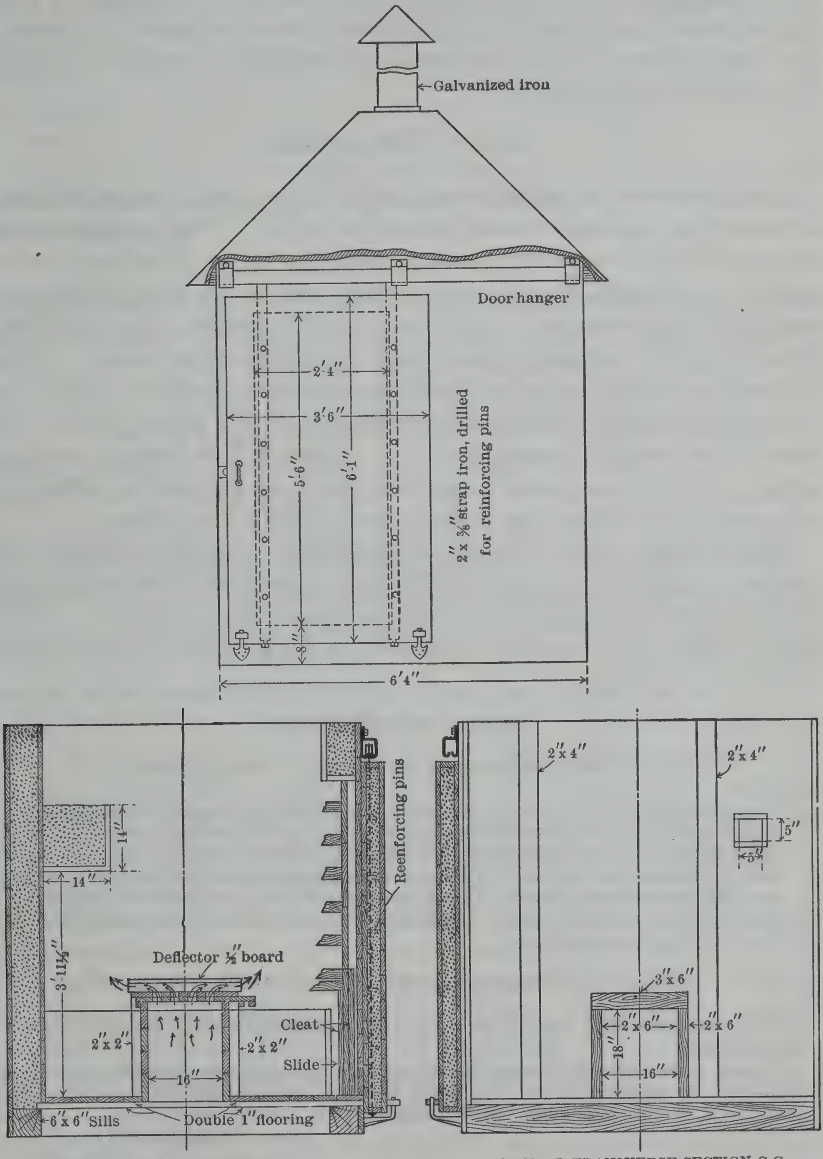
[b] See "working agreement between operators and miners," p. 97.



EXPLOSIVES TRAY
(3-Mesh brass screening)

HEAT REGULATOR SLIDE

HEAT REGULATOR



VERTICAL TRANSVERSE SECTION B-B

VERTICAL TRANSVERSE SECTION C-C

FIGURE 5.—Elevation and details of Bureau of Mines cement-mortar thaw house.

chests with a capacity of about 220 pounds, the explosive being taken in and stored after the shift has left the mine. Explosive is then delivered to miners at their working places by the powder man on the following morning and a receipt obtained. Another method of designating the owner is to paint the miner's check number in red on the end of the box. The amount of explosive delivered per day varies, usually the greatest amount being at the beginning of a two-weeks' pay, as the men will often postpone ordering for a day or two when the close of a two-weeks' period is near. In some of the larger mines the total amount of permissible explosive used per day averages 700 pounds.

USE OF POWDER BOXES.

The Illinois coal-mining law states that the explosive must be kept in a wooden box, securely locked, with a hinged lid. The boxes are usually kept in the first or second crosscut from the face. The law does not specify the dimensions of the powder box to be used, but for the most part boxes made of 1-inch board, of convenient shape and large enough to hold the allowable amount of explosive, are used. A great diversity of boxes exists; probably about three-fourths of the boxes in use fully comply with the requirements of the mining law. Some mines show marked superiority over others in this respect, and, to a certain extent, the conditions of storage of explosives reflect the attitude of officials in the enforcement of safety measures.

Mine inspectors and officials are constantly urging compliance with the law in detail, and particularly that boxes should never be placed where power cables may be laid in proximity to them. The following notice is an example of the efforts being made in this direction:

NOTICE TO EMPLOYEES.

EXTRACT FROM ILLINOIS STATE MINING LAWS (SECTION 19).

"*Place and manner of keeping in the mine.*—(*b*) Every person who has powder or other explosives in a mine shall keep the same in a wooden box, securely locked, with hinged lid, and said box shall be kept as far as possible from the track; and all powder boxes shall be kept as far as practicable from each other and each in a scheduled place. Black powder and high explosives or caps shall not be kept in the same box. Detonating explosives and detonators shall not be kept in the same box."

NOTICE TO EMPLOYEES OF THE ——— COAL MINING CO.

This company will require an immediate compliance with the above provisions of law.

Miners must provide themselves at once with lock boxes, keeping explosives and caps in separate boxes, and keep boxes in crosscuts as far as practicable from face of coal and from motor tracks.

——— Coal Mining Co.,
——— *Gen. Mgr.*

Tack this notice on your powder box.

DELIVERY AND STORAGE OF FUSE AND DETONATORS.

Necessary fuse and detonators are carried into the mines by the individual miners. Fuse is taken into the mine in rolls of 50 to 100 feet. Double tape fuse is used almost exclusively. This is an advantage, for even in dry mines wet holes are occasionally encountered, and a cheaper grade of fuse would be false economy. During the slack summer season a roll of fuse may not be completely used in three to four months. The ingredients in fuse, both the powder and the hemp wrapping, readily absorb moisture, and if the fuse is exposed to the damp floor of the mine or the moist air current it will become damp and be liable to cause misfires or dangerous hangfires. Because of the safety and economy in proper storage, it would be desirable to supply an air-tight container, which could be furnished at small cost to each miner, suitable for holding a roll of fuse and a box of detonators.

DETONATORS.

Detonators, or blasting caps, are supplied at normal prices to the miners in boxes of 100 at a cost of approximately $1 per box for the No. 6 grade. These are used almost exclusively in Illinois. The same quantity of No. 5 detonators can be purchased for $0.15 to $0.25 less per box than No. 6 at the local hardware stores, and miners sometimes buy them, but consistent results can not be obtained with No. 5 detonators. Powder men contend that an explosive detonates with greater strength when a No. 6 detonator is used, and strongly urge the exclusive use of detonators of not less strength than No. 6, which is one of the requirements of permissibility. With some permissible explosives a No. 7 detonator must be used. If the explosive has been stored for a period of approximately six months in the magazine, or if it has become damp in the miner's box underground or in a damp drill hole, the use of a No. 5 detonator is not only inefficient but dangerous. Under these conditions it is probable that a No. 5 detonator will not detonate the explosive properly, but will cause a misfire, or blow the stemming and part of the explosive out of the drill hole, or merely ignite the explosive, and start a fire or an explosion.

It is quite probable that detonators kept underground without careful storage for two or three months may become damp and weak. Tests have shown that when detonators become damp as little as one-sixth of the fulminate has been known to explode, which is insufficient to detonate a stick of explosive. The 100-detonator boxes are provided with a sheet of blotting paper which is supposed to keep out moisture, being laid on top of the caps and the cover placed over it. This sheet fulfills its purpose when the box is full, but after the detonators fall from the vertical position, it does not cover the ends of the detonators and furnishes little protection from moisture. Some miners recognize this fact and stuff cotton or paper over the detonators in the box to remedy this defect; others who do not take such precautions find that they have frequent misfires. To offset this, R. M. Medill, superintendent of the Dering Coal Co., first introduced detonators in boxes of 25 each in Franklin County. Some companies have lately been furnishing detonators in moisture-proof packages of 10 each. The detonators are so packed that they do not come in contact. With this style of package the miner can always feel sure of having a strong detonator and the packages are safer to handle than an ordinary box of detonators. (See Pl. V, *A*.) They are furnished at a small increase in cost. A box that is sometimes used contains a perforated partition which serves to hold the detonators upright in the box, even after most of them have been removed, and a piece of blotting paper covers their open end. A box of this type used in metal mines and quarries is illustrated in Bulletin 80[a] of the bureau. Such a box can be used indefinitely, as the detonators can be sold loose to the miners in small quantities not to exceed 25 at a time.

At a few mines the miners obtain their detonators at the shaft bottom. This is regarded as a much better practice than where the miners obtain them on the surface and then descend on the cage.

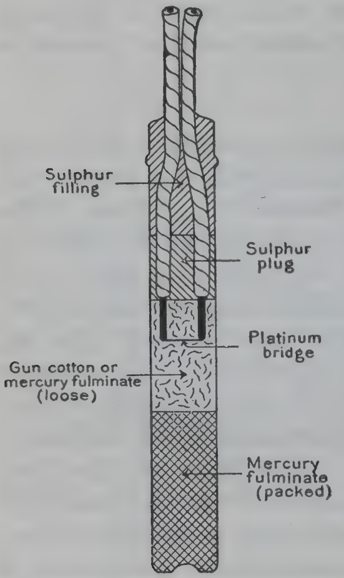

Sulphur filling
Sulphur plug
Platinum bridge
Gun cotton or mercury fulminate (loose)
Mercury fulminate (packed)

FIGURE 6.—Electric detonator, showing its component parts.

ELECTRIC DETONATORS.

In two mines electric detonators are supplied to the miners in boxes containing 50 each. No. 6 electric detonators with 8-foot iron wires are used. No. 6 electric detonators with 8-foot copper wires were formerly used but have been practically replaced by the detonators with iron wires. (See fig. 6, which shows component parts of electric detonators.)

Many of the difficulties attending the use of fuse and detonators are eliminated by the use of electric detonators, as they are not easily affected by moisture and do not require any preparation by the miner. Plate V, *B*, shows boxes of detonators and electric detonators.

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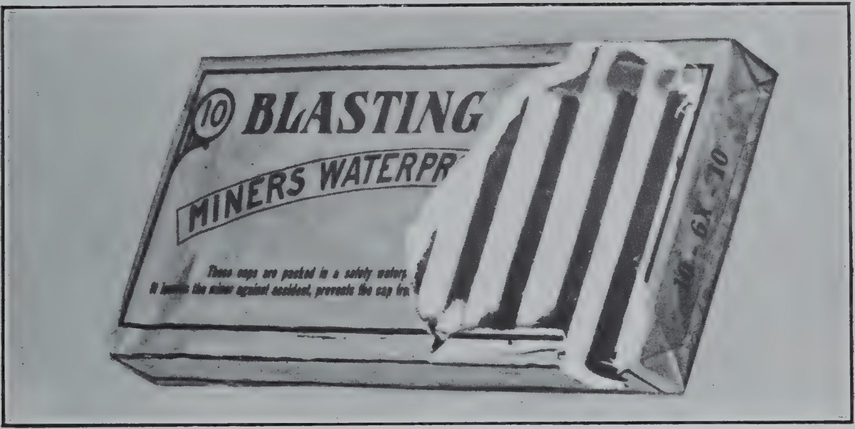
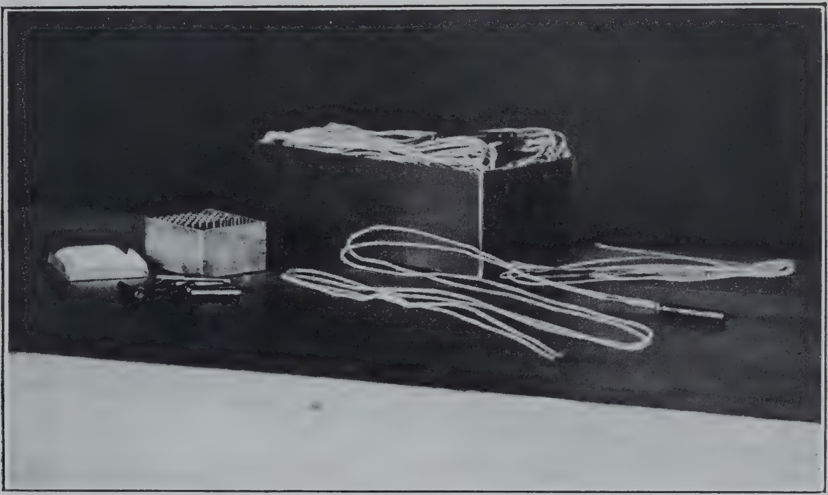
[a] Munroe, C. E., and Hall, Clarence, A primer on explosives for metal miners and quarrymen; Bull. 80, Bureau of Mines, 1915, p. 41.



A. MOISTURE-PROOF PACKAGE HOLDING TEN DETONATORS.



B. DETONATORS AND ELECTRIC DETONATORS.

SYSTEMS OF BLASTING.

UNDERCUTTING AND "SNUBBING."

In the Illinois coal mines using permissible explosives the undercutting is done in the bottom coal adjacent to the under clay. In 18 of the mines listed all undercutting is done with breast chain machines. Only one of these mines uses the "short-wall" type of machine exclusively, which cuts across the face after first "sumping" in. Two other mines have a few "short-wall" machines. Puncher machines are used in two of the mines listed; in one of these all the coal is undercut entirely by puncher machines; in the other the output is about equally divided between puncher and chain machines.

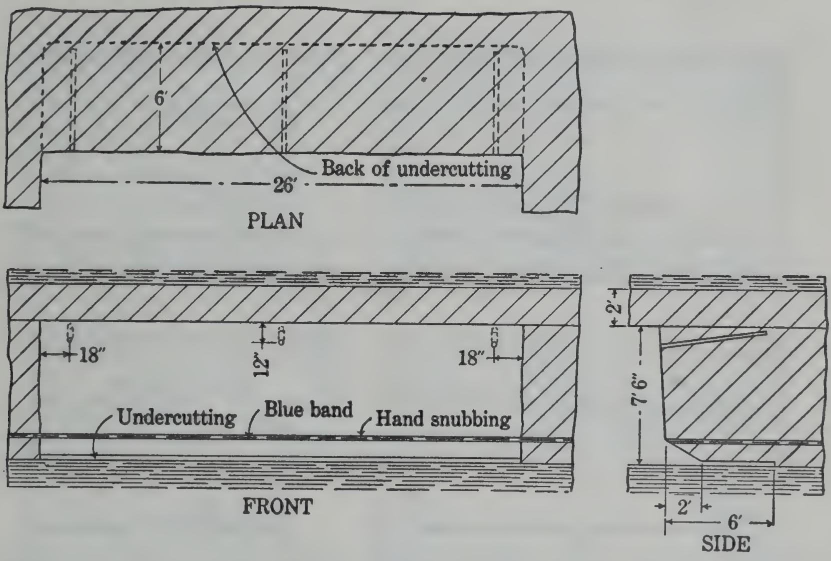


FIGURE 7.—Arrangement of drill holes, No. 6 seam, typical of practice with permissible explosives; coal undercut by chain machine, pick and wedge method of snubbing.

After the coal in the No. 6 seam has been undercut by chain machine it is generally "snubbed," either by sledge and wedge or by pick on a sloping face extending from the "blue band" to about one-half the depth of the undercut, as shown in figure 7. This system of snubbing previously followed in the Staunton field as early as 1897, was introduced in Franklin County by the agreement between Franklin County operators and miners. All cuttings are required to be loaded out before any shooting is done. Sometimes "snubbing shots" are fired.

Figure 8 shows methods of snubbing in entries. In entry work the most general practice is hand snubbing and shooting the coal with two holes, as shown at A. In one new mine where development work has been progressing rapidly, the firing of one snubbing shot, as shown at B, has been used with good results. In the thicker coal two snubbing shots are fired in entries, as shown at C.

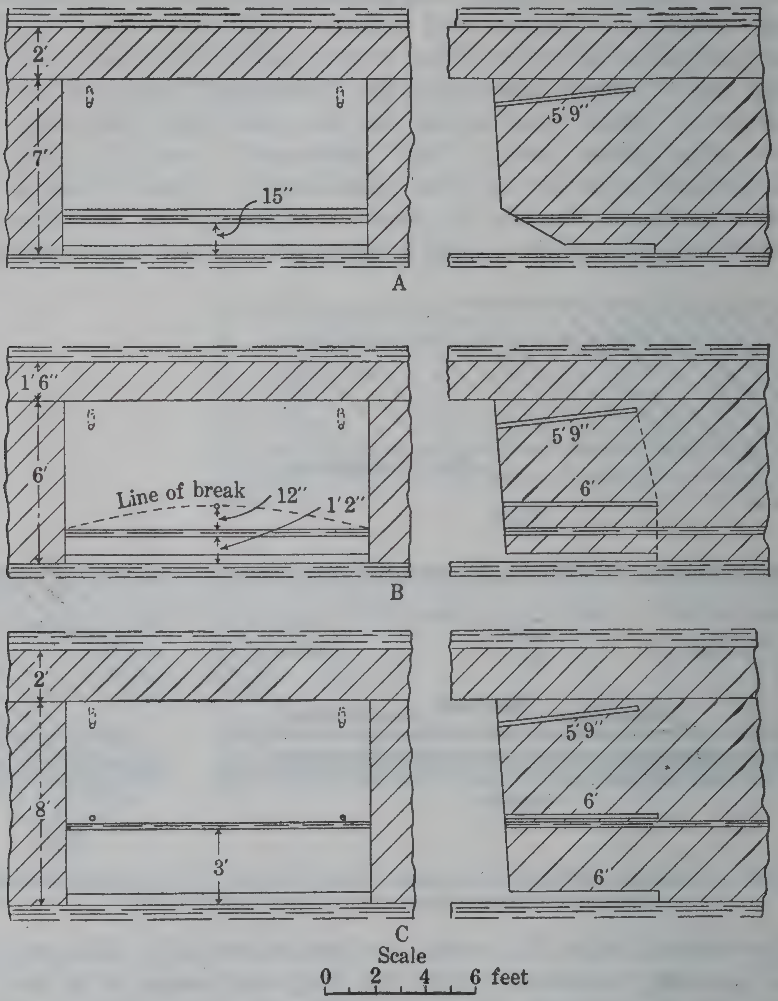


FIGURE 8.—Arrangement of drill holes in entry work, No. 6 seam, typical of practice with permissible explosives.

LOCATION AND ARRANGEMENT OF DRILL HOLES FOR PERMISSIBLE EXPLOSIVES.

The size of drill hole used in these mines averages 2¼ to 2½ inches in diameter. The two common types of drills in use ("post" and "grip") are shown in Plate II, *B* and *C*.

There is an agreeable uniformity in the general arrangement of shots in the various mines in which permissible explosives are used. The working dimensions are uniform for the most part, rooms being

24 to 26 feet in width. The height of coal worked varies from 7 to 10 feet, 7½ to 8 feet being the average; 10 to 40 inches of top coal is left for roof. A typical representation of the drill holes as to length, location, and arrangement in rooms for mines working the No. 6 seam in which the coal is undercut by chain machines is shown in figure 7; figure 8 gives similar details for entries. Figure 9 shows the arrangement of shots in mining the No. 5 coal, in which no top bench is left for roof.

In rooms the face is usually shot with three holes drilled parallel with the rib and about 12 inches from the roof, consisting of a center hole and two rib holes drilled about 18 inches from the ribs. The holes usually slope upward about 8° or 10° and are drilled to a depth equal to or slightly less than the depth of the undercutting, which varies from 4½ to 5 feet with puncher machines and from 5 to 7 feet with chain machines.

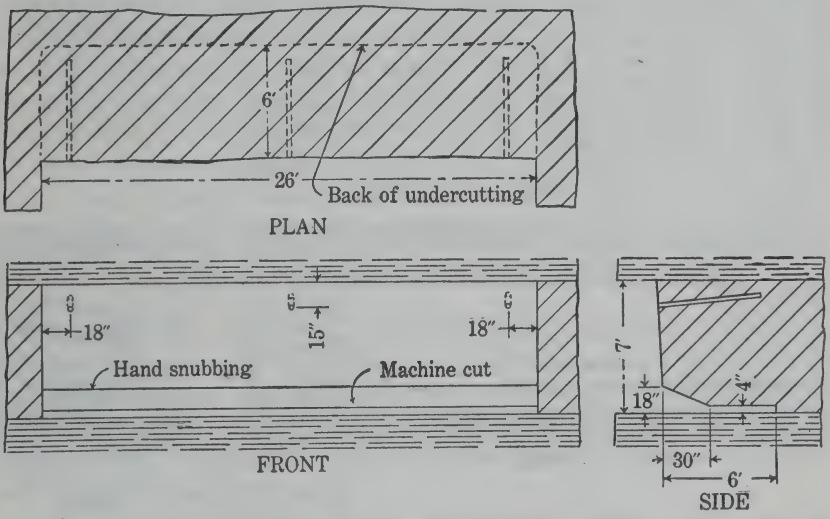


FIGURE 9.—Arrangement of drill holes, No. 5 seam, coal undercut by chain machine, hand snubbing.

There are a number of modifications of this method. In some instances holes are drilled as far as 2 to 3 feet from the rib and about 18 inches from the roof. In some mines horizontal holes are drilled, and these give good results, but usually on account of the height of the coal and the difficulty of drilling so close to the roof, the holes are given a slight angle. Undoubtedly the best results are obtained when the hole is only slightly inclined and the depth of the hole is about 6 to 12 inches less than the depth of undercutting. Usually in mining the coal breaks along certain faces independent of the angle of the drill hole, but in the No. 6 coal the cleat is not very pronounced. The advantage of inclining the holes is to cross the bedding planes which in some places are distinct. Drill holes should not be deeper than within 6 inches of a vertical plane through the back of the undercutting. Holes drilled so that the point is close to the rib or is in solid coal at the back require more explosive and yield a smaller proportion of lump coal. In entry work in these mines generally two holes are used. Sometimes the hole for the "buster" shot, which is always given the shortest fuse in order to insure its being fired first, is drilled about 18 inches from one of the ribs, and the hole for the second shot is drilled 9 to 12 inches from the other rib. On the next round the position of the "buster" shot and the second shot is reversed, thus maintaining a square rib.

When black blasting powder was formerly used in these mines, five holes were fired as shown in figure 10. The two shots immediately above the "blue band" acted as "snubbing" shots. At the outset a number of miners practiced the same method with permissible explosive, firing snubbing shots. This method is used to some extent at Zeigler and Sesser in mining thick coal—9 or more feet thick—and is strongly recommended as smaller charges of explosive can be used per shot and the limit charge will not be exceeded, but the general practice throughout the field is hand snubbing. In some places in the Zeigler-Christopher field the "blue band" becomes so thick, about 12 inches, that it is left in place, serving as the bottom. When the work to be done requires the use of an excessive amount of explosive in three holes, then a greater number of holes should be drilled.

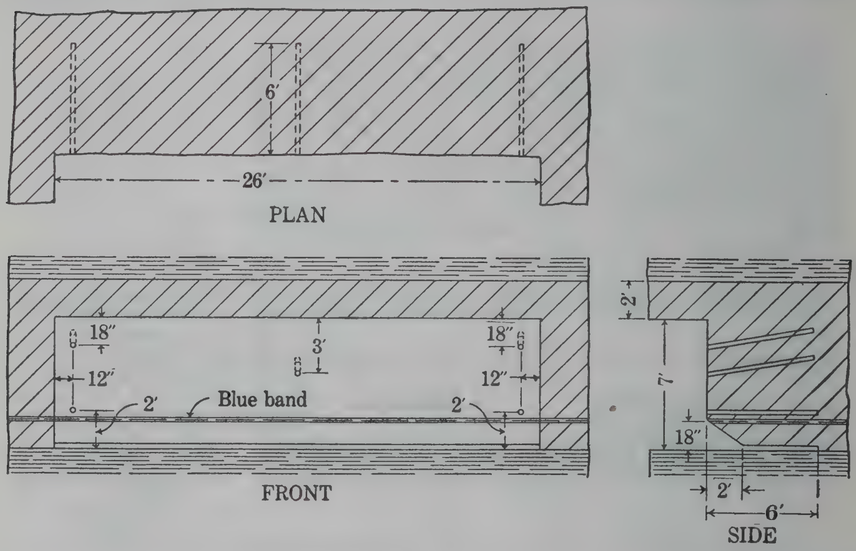


FIGURE 10.—Arrangement of drill holes, No. 6 seam, typical of practice in Franklin County when black blasting powder was used and snubbing was done by powder, in mines where permissible explosives are now used. Method of snubbing with permissible explosives used in coal 9 to 10 feet thick.

Permissible explosives have been used in shooting off the solid to some extent in drawing pillars and have given good results. It has been found that these explosives can be used to good advantage in shooting out the bottom bench below the "blue band;" then the remaining coal is shot down as when undercut. Their use has worked satisfactorily in a number of instances in "slabbing" entries and in recovering top coal.

In a certain Franklin County mine, hand mining is done in some few scattered rooms which are too far removed from the machine districts to be economically handled on the machine basis. Usually expert miners are assigned to such places. Cutting is done by hand immediately above the middle bench in the brittle layers of coal about 2 feet from the coal roof. Cutting is readily accomplished to a depth of 5 to 5½ feet. When the "weight" comes on the coal the work of hand mining is comparatively easy. Permissible explosives are used exclusively in this mine and give satisfactory results in shooting up the bottom bench, and only light charges are required to loosen the top bench, often only two short holes being necessary to shoot the top mass loose in a 24-foot room. Miners working in these rooms gain a larger tonnage per box of explosives used than the average for the regular machine districts of the mine.

QUANTITY OF EXPLOSIVE USED.

The amount of "snubbing" determines to a large extent the success obtained with permissible explosives. When the coal is well snubbed to a depth of 3 feet, the mass loosened by the shot tends to fall over, with the result that the coal is won easily and without special danger. Less explosive is used and the grade of coal obtained is better than without snubbing.

In the mines in the No. 6 coal, the charge when three shots are fired per room is usually three and one-half to four sticks, or 1¾ to 2 pounds, for the center or "buster" shot, and three sticks, or 1½ pounds, for each of the rib shots. Practice varies somewhat in the different mines; in some as many as five sticks are used in the center shot, with four in each of the rib shots. One instance was noted in which six sticks were used for the center shot and five for each of the rib shots. This is in excess of the limit charge of 1½ pounds which the Bureau of Mines has determined as the maximum safe loading charge per hole; a greater number of holes should be employed with less explosive per hole. Sometimes four holes are drilled to meet these conditions.

The usual practice is to use a slightly heavier charge for the "buster" or center shot than for the rib holes. In some mines a number of the miners used three sticks of explosive per hole, including the center shot. In such instances, however, the amount used was sufficient to break the coal down in the center.

In one mine in the No. 5 coal, the practice of using a lighter charge for the center shot was found to give good results. Two sticks of explosive were fired in the center shot and three in the rib shots. The center shot caused the coal merely to sag, tending to break the mass free from the ribs. The effects of these two methods are shown in figures 11 and 12.

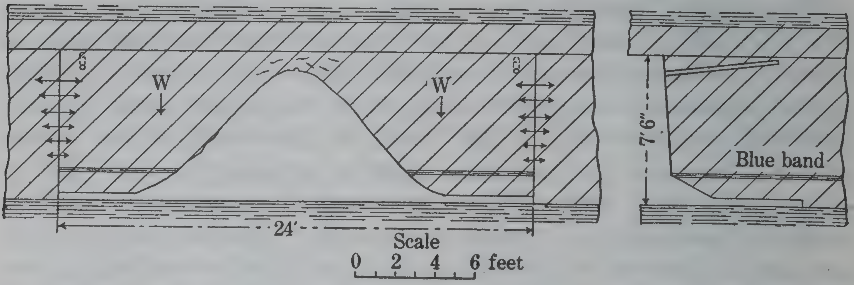


FIGURE 11.—Diagram showing effects of charging center shot heavier than the rib shots, showing tendency of remaining coal to break from ribs after partial removal of center support.

In figure 11, the arrows at either rib indicate the tension thrown on the coal at the rib by the weight of the mass W, which, through the partial removal of the center support by the "buster" shot, acts as a cantilever to break the remaining coal free from the ribs. As the coal does not have much tensile strength, the weight of the partly supported mass undoubtedly helps to break the coal free when the rib shots are fired.

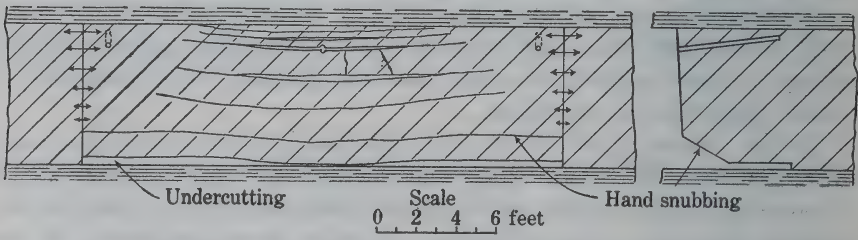


FIGURE 12.—Diagram showing lines of stress when coal is undercut and sagging in the middle from the discharge of a light center shot.

The reason for using a heavier charge for the "buster" shot is to give two loose ends for the rib shots. The "buster" shot loosens a somewhat circular mass at the center of the face, which on account of the snubbing tends to fall forward. When the rib shots are fired, there is a side thrust, and the coal from these shots tends to sink down on the coal loosened by the "buster" or center shot.

When the center shot is fired light, as shown in figure 12, the effect is different. When such a shot is fired, the full length of the coal across the face acts as a partly supported beam, which tends to sag in the middle. The burden on the center shot when the coal has been undercut to a depth of 6 feet is much less than on the rib shots. The fact that the center shot is charged light and merely loosens the coal at the center but does not break it tends to cause a greater tension on the upper part of the rib, which aids the action of the explosive in the corner or rib shots. It is necessary that the rib shots shall be shearing shots, and with thick coal this makes a heavy burden on the shot. With the center sagging and tending to pull the coal from the ribs, the rib shots have less work to do and throw the coal slightly forward. Much, of course, is dependent on the character of the coal and its resistance to shearing action.

Table 3 gives records of shots with permissible explosives in typical mines in Franklin and Saline Counties, with data on the method of placing, drilling, and loading the hole, dimensions of hole, amount of explosive used, and coal produced.

TABLE 3.—*Records of shots with permissible explosives in typical mines, showing data on method of placing, drilling, and loading the holes, amount of explosive used, and coal produced.*

MINES IN FRANKLIN COUNTY.

MINE A.

Place where shots were fired.	Width of room or entry.	Height of coal.	Depth of undercutting.	Snubbing.		Position of hole.[a]	Depth of hole.	Distance of hole from roof.	Distance of hole from rib.	Number of sticks of explosive used.	Length of fuse.[b]	Depth of stemming.	Total sticks of explosive used.	Total cars of coal produced.	Total tons of coal produced.	Total pounds of explosive used.	Tons of coal produced per 25-pound box of explosive.
				Depth.	Height.												
Room work.[c]																	
Entry 7 S. off 4 E. S.:	*Ft. ins.*	*Ft. ins.*	*Ft. ins.*	*Ft. ins.*	*Ft. ins.*		*Ft. ins.*	*Ft. ins.*	*Ft. ins.*		*Ft. ins.*	*Ft. ins.*			*Tons.Cwt.*		
Room 11	27 0	7 10	6 0	2 0	1 9	L.	5 10	1 3	2 0	3½	8 E.	3 0	10½	12	50 0	5.9	212
						C.	5 9	1 3	....	3½	8 E.	3 0					
						R.	5 10	1 3	2 2	3½	8 E.	3 0					
Room 19	27 6	7 3	6 0	2 0	1 8	L.	5 10	1 1	2 3	3½	8 E.	2 8	10½	11	46 0	5.9	195
						C.	5 10	1 0	....	3½	8 E.	2 8					
						R.	5 10	1 1	2 3	3½	8 E.	2 8					
Room 21	29 1	7 7	6 0	2 6	1 6	L.	5 10	1 0	2 0	4	8 E.	2 8	12	13	50 12	6.75	187
						C.	5 10	1 0	....	4	8 E.	2 8					
						R.	5 10	1 0	2 0	4	8 E.	2 8					
Room 22	27 9	7 8	6 0	2 6	1 6	L.	5 9	1 0	2 0	4	8 E.	2 10	12	12	49 0	6.75	181
						C.	5 9	1 0	....	4	8 E.	2 10					
						R.	5 9	1 0	2 0	4	8 E.	2 10					
Room 23	25 0	7 9	5 11	2 0	1 6	L.	6 0	1 0	2 0	4	8 E.	3 0	12	12	48 18	6.75	181
						C.	6 0	1 0	....	4	8 E.	3 0					
						R.	6 0	1 0	2 0	4	8 E.	3 0					
Room 24	24 0	7 6	6 0	2 0	1 6	L.	5 10	1 0	2 0	4	8 E.	2 10	12	13	52 15	6.75	195
						C.	5 10	1 0	....	4	8 E.	2 10					
						R.	5 10	1 0	2 0	4	8 E.	2 10					
Total for 6 rooms	....	....	....	....	....	......	....	....	....	....	....	....	69	73	297 5	38.80	1,151
Average[d]	26 8	7 7	6 0	2 2	1 7	......	5 10	1 1	2 ⅔	3.8	8	2 10	11½	12	49 11	6.47	192
Entry 8 S, off 4 E. S.:																	
Room 24	28 0	7 7	6 11	3 0	1 6	L.	7 0	0 11	2 3	3	8 E.	3 0	9½	14	58 0	5.3	274
						C.	7 0	1 0	....	3	8 E.	3 0					
						R.	7 0	1 0	2 3	3½	8 E.	3 0					

Room 16	27 6	7 10	6 10	2 8	1 6	L.	6 0	1 2	2 2	3½	8 E.	2 8	10	14	55 0	5.6	246
						C.	6 2	1 3	....	3	8 E.	2 8					
						R.	6 1	1 2	2 2	3½	8 E.	2 8					
Room 14	29 0	8 4	7 0	2 8	1 6	L.	6 10	1 0	2 0	3½	8 E.	3 0	10	15	63 0	5.6	281
						C.	6 10	1 0	....	3½	8 E.	3 0					
						R.	6 10	1 0	3 0	3	8 E.	3 0					
Room 9	27 9	8 2	7 0	2 6	1 6	L.	6 9	0 11	1 3	3	8 E,	2 10	10	14	56 8	5.6	252
						C.	6 9	0 11	....	4	8 E.	2 10					
						R.	6 9	1 2	3 0	3	8 E.	2 10					
Room 6	26 0	8 0	7 0	2 4	1 6	L.	6 10	1 0	2 0	3	8 E.	2 6	10	13	52 0	5.6	232
						C.	6 10	1 0	....	4	8 E.	2 6					
						R.	6 10	1 0	2 2	3	8 E.	2 6					
Total for 5 rooms	......	......	......	......	......	......	......	......	......	......	......	......	49½	70	284 8	27.7	1,285
Average *e*	27 8	8 0	6 11	2 8	1 6	......	6 9	1 0	2 3	3.3	8	2 10	9.9	14	56 18	5.5	257
Entry 9 S. off 4 E. S.:																	
Room 2	27 6	7 6	5 8	1 4	2 0	L.	5 8	1 0	2 6	3	8 E.	2 6	9½	12	49 4	5.3	232
						C.	5 8	1 0	....	3½	8 E.	2 6					
						R.	5 8	1 0	2 4	3	8 E.	2 6					
Room 3	26 0	7 11	5 8	1 6	2 2	L.	5 8	0 11	2 10	3	8 E.	2 8	9½	14	56 14	5.3	267
						C.	5 6	1 0	....	3½	8 E.	2 8					
						R.	5 6	1 0	2 6	3	8 E.	2 8					
Entry 10 S. off 4 E. S.:																	
Room 4	28 6	8 1	5 8	1 6	1 6	L.	5 8	1 2	3 3	3	8 E.	2 10	10	11	45 2	5.6	201
						C.	5 8	1 3	....	4	8 E.	2 10					
						R.	5 8	1 2	2 3	3	8 E.	2 10					
Room 1	27 0	8 2	5 8	2 6	1 6	L.	5 9	1 0	2 8	3	8 E.	3 0	9½	12	49 4	5.3	232
						C.	5 7	1 0	....	3	8 E.	3 0					
						R.	5 9	1 0	3 0	3½	8 E.	3 0					
Total for 4 rooms	......	......	......	......	......	......	......	......	......	......	......	......	38½	49	200 4	21.5	932
Average	27 3	7 11	5 8	1 9	1 10	......	5 8	1 1	2 8	3½	8	2 9	9.6	12½	50 1	5.4	233
Entry 8 S. S. E.:																	
Room 19	26 0	8 0	6 6	4 0	3 6	L.	6 6	0 11	2 0	3½	8 E.	4 0	10½	14	58 0	5.9	246
						C.	6 6	1 0	....	3	8 E.	4 0					
						R.	6 6	1 0	2 0	4	8 E.	4 0					
Room 20	25 6	8 0	6 6	3 0	2 6	L.	6 6	1 2	2 0	3	8 E.	4 0	10	13	54 10	5.6	243
						C.	6 6	1 3	....	3	8 E.	4 0					
						R.	6 6	1 2	2 0	4	8 E.	4 0					

[a] L signifies left; C, center; and R, right.

[b] Letter E signifies that electric detonator was used.

[c] Shots fired by electric battery, No. 6 electric detonator with 8-foot leads used. Holes slope upward toward roof, back of hole being within 2 to 4 inches of the top. Parting ("blue band") ½ inch to ¾ inch thick. Face overhangs slightly, top projecting 1 to 2 feet. One round of shots per room.

[d] With 6-foot machine.

[e] With 7-foot machine.

TABLE 3.—*Records of shots with permissible explosives in typical mines, showing data on method of placing, drilling, and loading the holes, amount of explosive used, and coal produced*—Continued.

MINES IN FRANKLIN COUNTY—Continued.

MINE A—Continued.

Place where shots were fired.	Width of room or entry.	Height of coal.	Depth of undercutting.	Snubbing.		Position of hole.	Depth of hole.	Distance of hole from roof.	Distance of hole from rib.	Number of sticks of explosive used.	Length of fuse.	Depth of stemming.	Total sticks of explosive used.	Total cars of coal produced.	Total tons of coal produced.	Total pounds of explosive used.	Tons of coal produced per 25-pound box of explosive.
				Depth.	Height.												
Room work—Continued.																	
Entry 8 S. S. E.—Continued.	*Ft. ins.*	*Ft. ins.*	*Ft. ins.*	*Ft. ins.*	*Ft. ins.*		*Ft. ins.*	*Ft. ins.*	*Ft. ins.*		*Ft. ins.*	*Ft. ins.*			*Tons. Cwt.*		
Room 19 *a*	26 3	8 2	6 6	3 6	2 6	L.	6 6	0 11	2 0	3½	8 E.	4 0	10½	14	58 0	5.9	246
						C.	6 6	1 0	....	3	8 E.	4 0					
						R.	6 6	0 11	2 0	4	8 E.	4 0					
Total for 3 rooms	....	....	....	....	....	....	....	....	....	....	....	....	31	41	170 10	17.4	735
Average	25 11	8 1	6 6	3 6	2 10	......	6 6	1 0	2 0	3½	8	4 0	10⅓	13⅔	56 17	5.8	245
Entry 8 N. N. W.:																	
Rooms 24 and 25	27 0	8 0	5 6	3 0	2 0	L.	5 4	1 0	2 0	4	8 E.	3 0	11½	13	53 0	6.5	204
						C.	5 3	1 2	....	3½	8 E.	3 0					
						R.	5 4	1 0	2 6	4	8 E.	3 0					
	27 3	8 0	5 6	3 0	2 0	L.	5 4	1 4	2 0	4	8 E.	3 0	12	13	54 5	6.75	201
						C.	5 0	1 2	....	4	8 E.	3 0					
						R.	5 4	1 4	2 0	4	8 E.	3 0					
	27 0	8 2	5 6	3 0	2 0	L.	5 4	1 5	2 0	3½	8 E.	3 0	10½	14	54 0	5.9	229
						C.	5 4	1 2	....	3½	8 E.	3 0					
						R.	5 4	1 4	2 0	3½	8 E.	3 0					
Total for 3 rooms	....	....	....	....	....	....	....	....	....	....	....	....	34	40	161 5	19.15	634
Average	27 1	8 1	5 6	3 0	2 0	......	5 3	1 2	2 1	3 7/9	8	3 0	11⅓	13⅓	53 15	6.38	211
Grand total for 21 rooms	....	....	....	....	....	....	....	....	....	....	....	....	222	273	1,113 12	124.55	4,737
Grand average, 21 rooms, representative of room work in Mine A	27 0	7 11	6 2	2 6	1 10	......	6 0	1 1	2 3	3.5	8	3 0	10 4/7	13	53 1	5.9	226

Entry work.																	
Entry 10 S. E., off 4 E. S., average	11 2	6 10	5 6	2 6	2 0	L.	5 3	0 11	1 8	3½	8 E.	2 8	8	5	17 18	4.5	100
						R.	5 2	1 0	1 0	4½	8 E.	2 8					
Entry 9 S. E., off 4 E. S., average	11 8	7 0	6 0	2 0	2 0	L.	5 11	1 0	2 0	4	8 E.	2 8	8	5	18 0	4.5	100
						R.	5 10	1 0	1 0	4	8 E.	2 8					
Total for 2 entries	......	......	......	......	......	......	......	......	......	......	......	......	16	10	35 18	9.0	200
Average for entry work in Mine A	11 5	6 11	5 9	2 3	2 0	......	5 6	1 0	1 5	4	8	2 8	8	5	17 19	4.5	100
MINE B.																	
Room work.[b]																	
Room 19, entry 8 S. off 8 W. off main south entry.	29 6	7 9	6 9	2 2	1 7	L.	6 0	1 0	2 0	3	6	3 0	9	17	54 10	4.5	303
						C.	5 10	1 0	....	3	6	3 0					
						R.	6 2	0 11	2 0	3	6	3 0					
Entry 7 S. off 8 W. off main south entry:																	
Room 19	28 0	7 10	6 10	2 2	1 6	L.	6 3	1 2	2 9	3	6	3 0	9	18	56 0	4.5	311
						C.	6 2	1 3	....	3	6	3 0					
						R.	6 4	1 3	2 0	3	6	3 0					
Room 16	24 0	7 8	6 9	2 2	1 6	L.	6 3	1 0	2 2	3	6	3 0	10	17	51 15	5.0	259
						C.	6 6	1 1	....	4	6	3 0					
						R.	6 4	1 0	2 3	3	6	3 0					
Total for three rooms	......	......	......	......	......	......	......	......	......	......	......	......	28	52	162 5	14.0	873
Average[c]	27 2	7 9	6 9	2 1	1 6	......	6 2	1 1	2 2	3	6	3 0	9⅓	17⅓	54 2	4.7	291
Entry 6 S. off 10 W. off main south:																	
Room 32	22 0	7 8	5 3	2 4	1 6	L.	4 9	1 2	2 0	3	5 6	2 8	9	12	35 10	4.5	197
						C.	4 8	1 1	....	3	5 3	2 6					
						R.	4 9	1 1	2 2	3	5 6	2 8					
Room 30	21 0	7 6	5 6	2 6	1 6	L.	5 3	1 0	1 6	2½	5 3	3 0	8½	11	34 0	4.25	206
						C.	5 0	1 0	....	3	5 0	3 0					
						R.	5 3	1 0	2 0	3	5 3	3 0					
Room 31	21 6	7 6	5 6	2 6	1 6	L.	5 3	1 0	1 6	3½	5 6	3 0	9½	12	35 0	4.75	184
						C.	5 0	1 0	....	3	5 0	3 0					
						R.	5 3	1 0	1 6	3	5 6	3 0					
Room 30, entry 5 S. off 10 W. off main south.	22 0	7 5	5 0	2 0	1 7	L.	4 9	1 2	2 0	2½	5 3	2 8	7½	11	33 0	3.75	220
						C.	4 8	1 2	....	2½	5 3	2 8					
						R.	4 9	1 0	1 6	2½	5 3	2 8					
Entry 3 N.:																	
Room 19	24 0	7 6	5 0	2 0	1 8	L.	5 0	1 0	1 11	3	5 6	2 6	9	11	34 2	4.5	189
						C.	5 0	1 0	....	3	5 6	2 6					
						R.	5 0	1 0	2 2	3	5 6	2 6					
Room 20	24 3	7 6	5 0	2 0	1 10	L.	5 0	1 0	1 8	3	5 6	2 8	9	10	34 0	4.5	189
						C.	5 0	1 0	....	3	5 6	2 8					
						R.	5 0	1 0	2 0	3	5 6	2 8					

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[a] Data taken one week after above data for this room was taken.

[b] Holes incline toward roof about 1 inch per foot. Data show that the "buster" shot often produced one-half of the coal. Face overhangs slightly.

[c] Seven-foot machine and wide rooms.

TABLE 3.—*Records of shots with permissible explosives in typical mines, showing data on method of placing, drilling, and loading the holes, amount of explosive used, and coal produced*—Continued.

MINES IN FRANKLIN COUNTY—Continued.

MINE B—Continued.

Place where shots were fired.	Width of room or entry.	Height of coal.	Depth of undercutting.	Snubbing.		Position of hole.	Depth of hole.	Distance of hole from roof.	Distance of hole from rib.	Number of sticks of explosive used.	Length of fuse.	Depth of stemming.	Total sticks of explosive used.	Total cars of coal produced.	Total tons of coal produced.	Total pounds of explosive used.	Tons of coal produced per 25-pound box of explosive.
				Depth.	Height.												
Room work—Continued.																	
Entry 3 N.—Continued.	*Ft. ins.*	*Ft. ins.*	*Ft. ins.*	*Ft. ins.*	*Ft. ins.*		*Ft. ins.*	*Ft. ins.*	*Ft. ins.*		*Ft. ins.*	*Ft. ins.*			*Tons. Cwt.*		
Room 21	24 6	7 6	5 1	1 8	1 9	L.	5 1	1 0	1 8	3	5 6	3 0	9	12	35 10	4.5	197
						C.	5 0	1 0	......	3	5 4	3 0					
						R.	5 0	1 0	2 0	3	5 6	3 0					
Total for seven rooms	......	......	......	......	......	......	......	......	......	......	......	......	61½	79	241 2	30.75	1,376
Average [a]	22 9	7 6	5 2	2 2	1 7	......	5 0	1 0	1 11	2.9	5 4	2 9	8.8	11.3	34 9	4.40	197
Average for room work in mine B	24 1	7 7	5 8	2 2	1 7	......	5 4	1 1	2 0	3	5 7	2 10	8.95	13	40 7	4.5	225
Widening out room neck.																	
Room 17, entry 6 S. off 8 E. S.	17 0	7 8	5 0	2 6	2 10	L.	4 6	1 5	2 0	3½	5½	2½	7	8	23 8	3.5	167
						R.	4 8	1 7	2 0	3½	5½	2½					
Narrow work (entries).[b]																	
Entry 9 W. off main south	12 0	6 8	6 8	1 0	2 0	L.	6 8	0 11	1 6	5	6 0	3 0	9	7	21 2	4.5	117
						R.	6 11	0 11	1 8	4	6 0	3 0					
Entry 8 S. off 10 W. off main south	11 8	7 0	6 8	1 0	2 0	L.	6 6	0 11	2 0	5	6 0	3 0	9	7	21 5	4.5	118
						R.	6 6	1 0	1 2	4	6 0	3 0					
Entry 3 S. off 12 E. S.	12 6	7 4	5 4	3 0	2 6	L.	5 2	1 0	2 0	5	4 6	2 0	9	6	19 0	4.5	106
						R.	5 3	1 0	2 0	4	5	2 0					
Entry 2 S. off 12 E. S.	12 6	7 4	5 6	2 6	2 4	L.	5 0	1 0	2 0	5	4 6	2 4	9	7	22 0	4.5	122
						R.	5 0	1 0	2 0	4	5	2 4					
Entry 13 E. S.	12 0	7 4	5 4	2 1	2 0	L.	5 4	1 6	1 10	5	4 6	2 6	9	6	19 10	4.5	108
						R.	5 0	1 6	1 10	4	5	2 6					
Entry 4 S. off 8 E. S.	12 0	7 0	5 0	2 0	2 2	L.	5 0	1 0	1 6	3	5	2 4	7	6	18 5	3.5	130
						R.	5 2	1 2	1 7	4	4 6	2 4					
Do	12 0	7 1	5 0	2 0	2 2	L.	5 0	1 0	1 6	3	5	2 2	7	6	18 0	3.5	129
						R.	5 0½	1 2	1 7	4	4 6	2 2					

Entry 5 S. off 8 E. S.	13 8	7 5	5 0	2 11	2 10	L.	4 8	1 0	2 0	3	5 6	2 4	7	6	17 13	3.5	126
						R.	4 7	1 0	2 1	4	5 6	2 4					
Do.	13 8	7 5	5 0	3 0	2 10	L.	4 8	1 0	2 1	3	5 6	2 6	7	6	18 0	3.5	129
						R.	4 6	1 0	2 0	4	5 6	2 6					
Total for nine entries	......	......	......	......	......	......	......	......	......	......	......	......	73	57	174 15	36.5	1,085
Average for entry work in Mine B	12 4	7 2	5 6	2 2	2 4	......	5 4	1 1	1 10	4	5 2	2 6	8.1	6.3	19 8	4.1	121
MINE C.																	
Room work.[c]																	
Entry 2 S. W., off No. 4 stub:																	
Room 8	28 0	7 9	5 6	2 6	1 6	L.	5 0	1 0	1 6	4	6 0	2 6	13	13	43 0	6.7	160
						C.	5 0	1 0	....	5	4 0	2 0					
						R.	5 0	1 0	1 6	4	5 0	2 6					
Room 9	28 5	7 8	5 6	2 5	1 6	L.	5 2	1 0	1 6	4	5 6	2 6	13	13	43 10	6.7	162
						C.	5 0	1 0	....	5	5 0	2 6					
						R.	5 2	1 0	1 7	4	5 6	2 6					
Entry 2 S. W. off No. 6 stub:																	
Room 1	28 0	7 6	5 6	2 6	1 6	L.	5 0	1 6	2 0	4	6 0	3 0	12½	13	42 5	6.4	165
						C.	4 9	1 6	....	4½	5 6	3 0					
						R.	5 0	1 6	2 6	4	5 10	3 0					
Room 2	27 8	7 8	5 6	2 6	1 6	L.	5 2	1 3	2 0	4	5 8	3 0	12½	13	42 10	6.4	166
						C.	5 0	1 3	....	4½	5 4	3 0					
						R.	5 1	1 4	2 4	4	5 8	3 0					
Entry 4 N. W. off No. 2 stub:																	
Room 19	27 6	7 6	5 6	2 0	1 6	L.	5 0	1 3	3 0	4½	5 6	2 6	14	12	40 15	7.2	141
						C.	4 10	1 3	....	5	5 6	2 6					
						R.	5 1	1 0	2 0	4½	6 0	2 6					
Room 20	28 2	7 6	5 6	2 0	1 6	L.	5 1	1 0	2 0	4½	6 0	2 0	14	13	42 10	7.2	148
						C.	4 10	1 6	....	5	5 0	2 6					
						R.	5 1	1 0	2 0	4½	5 0	2 0					
Total for six rooms	......	......	......	......	......	......	......	......	......	......	......	......	79	77	254 10	40.6	942
Average for room work in Mine C	28 0	7 7	5 6	2 4	1 6	......	5 0	1 2	2 0	4.4	5 5	2 7	13	13	42 8	6.8	157
Entry work.																	
Entry 5 S. off 2 N. E	12 2	7 6	5 6	2 6	1 6	L.	5 0	1 0	1 6	4	6 0	2 6	9	6	19 0	4.6	103
						R.	5 0	1 0	1 6	5	5 0	2 0					
Entry 6 S. off 2 N. E	12 0	7 6	5 6	2 4	1 6	L.	5 0	1 0	1 5	5	5 0	2 0	9	6	18 10	4.6	101
						R.	5 0	1 0	1 6	4	6 0	2 6					
Entry 1 N. off No. 3 stub off 2 S. W	12 0	7 2	5 6	2 0	1 6	L.	5 1	1 0	1 6	4	6 0	2 0	9	6	18 10	4.6	101
						R.	5 1	1 0	1 6	5	5 6	2 0					
Entry 2 N. off No. 3 stub off 2 S. W	12 0	7 3	5 6	2 0	1 6	L.	5 2	1 0	1 6	4	6 0	2 6	8½	6	18 15	4.4	107
						R.	5 1	1 0	1 6	4½	5 6	2 6					
Total for four entries	......	......	......	......	......	......	......	......	......	......	......	......	35½	24	74 15	18.2	412
Average for entry work in Mine C	12 0	7 4	5 6	2 2	1 6	......	5 1	1 0	1 6	4.4	5 7	2 3	8.9	6	18 14	4.55	103

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[a] Short-wall machine, rooms of average width.

[b] Average for mine.

[c] Holes drilled on angle to strike top parting at back of hole. "Blue band" ¾ to 1 inch thick.

TABLE 3.—*Records of shots with permissible explosives in typical mines, showing data on method of placing, drilling, and loading the holes, amount of explosive used, and coal produced*—Continued.

MINES IN FRANKLIN COUNTY—Continued.

MINE D.[a]

Place where shots were fired.	Width of room or entry.	Height of coal.	Depth of undercutting.	Snubbing.		Position of hole.	Depth of hole.	Distance of hole from roof.	Distance of hole from rib.	Number of sticks of explosive used.	Length of fuse.	Depth of stemming.	Total sticks of explosive used.	Total cars of coal produced.	Total tons of coal produced.	Total pounds of explosives used.	Tons of coal produced per 25-pound box of explosive.
				Depth.	Height.												
	Ft. ins.	Ft. ins.	Ft. ins.	Ft. ins.	Ft. ins.		Ft. ins.	Ft. ins.	Ft. ins.		Ft. ins.	Ft. ins.			Tons. cwt.		
Room 10, entry 5 NE., off panel 6	23 0	7 5	6 0	3 0	1 11	L.	5 9	1 0	1 6	2½	5 8	2 10	9	12	36 1	4.6	196
						C.	5 10	0 10	....	3½	5 8	2 10					
						R.	6 0	1 0	2 2	3	5 8	2 10					
Room 6, entry 8 NE., off panel 2	22 6	7 11	6 0	2 9	1 7	L.	6 0	1 5	2 0	3	6 0	3 0	9½	12	36 4	5.1	177
						C.	6 1	1 1	....	3½	5 6	3 0					
						R.	6 0	1 2	2 8	3	6 0	3 0					
Entry 9 NE., off panel 1:																	
Room 7	23 0	6 7	6 0	2 4	1 4	L.	6 0	1 0	1 6	3	5 6	3 0	9½	11	33 13	5.1	165
						C.	5 9	1 2	....	3½	5 6	3 0					
						R.	6 0	1 0	2 7	3	5 6	3 0					
Room 3	23 0	7 2	6 0	2 9	1 3	L.	6 0	1 2	2 6	2¾	6 0	3 0	9½	11	33 10	4.8	174
						C.	6 3	1 0	....	3½	5 6	3 0					
						R.	5 11	1 3	2 0	3¼	6 0	3 0					
Room 10	23 0	7 5	6 0	2 4	1 6	L.	5 6	1 0	2 1	3½	5 6	2 8	10	11	32 13	5.2	157
						C.	6 0	1 0	....	4	5 6	2 8					
						R.	6 0	1 0	2 0	2½	5 6	2 8					
Entry 9 NE., off panel 2:																	
Room 10	24 0	7 2	6 0	2 9	1 7	L.	5 11	0 8	2 5	3¾	6 0	3 0	10½	11	34 10	5.6	154
						C.	5 8	0 8	....	3½	5 8	3 0					
						R.	5 11	0 8	2 5	3¼	6 0	3 0					
Room 12	24 0	7 2	6 0	2 9	1 7	L.	6 0	1 2	2	3½	6 0	2 10	9	11	33 10	4.7	178
						C.	6 0	0 7	....	3½	6 0	2 10					
						R.	6 0	0 10	2	2	6 0	2 10					
Entry 1 NW., off panel 6:																	
Room 5	23 6	7 0	6 0	3 0	1 8	L.	6 0	0 11	2 6	2½	5 6	3 0	9½	12	35 15	4.8	186
						C.	5 9	1 0	2 0	4	5 6	3 0					
						R.	5 9	0 11	2 6	3	5 6	3 0					
Room 18	23 6	7 0	6 0	3 0	1 8	L.	5 10	0 9	2 0	1½	5 6	2 10	8	12	37 15	4.2	225
						C.	5 11	0 8	....	3½	5 6	2 10					
						R.	5 11	0 8	2 4	3	5 6	2 10					
Entry 10 SE., panel 1:																	
Room 5	23 6	7 3	6 0	2 4	1 6	L.	6 0	1 0	2 4	2½	6 0	3 2	9	13	39 11	4.8	206
						C.	5 6	1 0	....	3½	5 6	3 2					
						R.	5 6	1 0	1 8	3	6 0	3 2					

Room 9	26 6	7 4	6 0	2 6	1 5	L.	5 10	1 7	1 9	2½	5 6	3 0	9½	14	42 13	4.8	222
						C.	5 4	1 0	......	4	5 6	3 0					
						R.	5 6	1 2	1 4	3	5 6	3 0					
Room 5, entry 10 SE., off panel 7	23 6	7 2	6 0	2 6	1 8	L.	5 2	1 0	2 3	2¼	5 0	3 0	10	12	37 11	5.2	180
						C.	5 2	0 10	......	4	5 0	3 0					
						R.	5 2	0 10	2 0	3¾	5 0	3 0					
Total for 12 rooms	......	......	......	......	......	......	......	......	......	......	......	......	113	142	433 06	58.9	2,220
Average for rooms of Mine D	23 7	7 3	6 0	2 8	1 7	......	5 10	1 0	2 2	3.1	5 8	2 11	9.4	11.8	36 02	4.9	185
MINE E.																	
Narrow work.																	
Entry 3 R	12 0	7 3	6 0	5 9	3 0	L.	5 10	1 0	1 6	3	5 6	2	b10½	5	19	5.25	90
						R.	5 10	1 0	1 6	3	5 6	2					
Entry 4 R	12 0	7 3	6 0	5 9	3 0	L.	5 9	1 0	1 6	3	5 6	2	b10½	5	20	5.25	95
						R.	5 9	1 0	1 6	3	5 6	2					
Entry 4 R	12 0	7 3	6 0	5 9	3 0	L.	5 10	1 0	1 6	3	5	2	b10½	5	19 10	5.25	93
						R.	5 9	0 10	1 6	3	5 6	2					
Entry 1 L., off 10 WS	12 2	7 6	6 0	5 6	3 6	L.	5 6	1 0	1 6	3	6	2	c12	5	20	6.0	83
						R.	5 6	1 0	1 6	3	6	2					
Entry 2 L., off 10 WS	12 1	7 6	6 0	5 6	3 6	L.	5 6	1 0	1 6	3	5 6	2	c12	5	21	6.0	88
						R.	5 6	1 0	1 6	3	6	2					
Total for 5 entries	......	......	......	......	......	......	......	......	......	......	......	......	55½	25	99 10	27.75	449
Average for narrow work at Mine E	12 1	7 4	6 0	5 8	3 2	......	5 8	1 0	1 6	3.0	5 7	2	11	5	19 18	5.55	90
Wide work.[d]																	
Entry A:																	
Room 10	29 0	10 0	5 6	5 3	3 0	L.	5 0	1 3	1 8	2½	6 6	4 6	e14	16	64	7.0	229
						C.	5 0	1 6	......	3	5 6	4 6					
						R.	5 0	1 3	1 8	2½	6 6	4 6					
Room 11	29 2	10 1	5 5	5 4	2 11	L.	5 0	1 4	1 8	3	6	4	e15	16	64 15	7.5	216
						C.	5 0	1 4	......	3	6	4					
						R.	5 0	1 4	1 8	2½	6	4					
Room 12	28 10	9 11	5 7	5 5	3	L.	5 2	1 3	2 0	2½	6	4	e14	16	65	7.0	232
						C.	5 2	1 3	......	3	6	4					
						R.	5 2	1 3	2 0	2½	6	4					
Room 15	30 0	9 6	5 8	5 4	3	L.	5 2	1 2	1 8	2	5 6	3 6	e13	15	60 10	6.5	233
						C.	5 1	1 1	......	2	5	3 6					
						R.	5 2	1 2	2 0	2	5 6	3 6					
Total for 4 rooms	......	......	......	......	......	......	......	......	......	......	......	......	56	63	254 05	28.0	910
Average for wide work in rooms	29 3	9 11	5 7	5 4	3 0	......	5 1	1 3	1 10	2½	5 10	4 0	14	16	63 11	7.0	228

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[a] Series of shots with 3 different brands of permissible explosives. All holes were parallel with rib and inclined to roof 1½ inches per foot.
[b] Including 4½ sticks of explosive in 2 snubbing shots.
[c] Including 6 sticks of explosive in 2 snubbing shots.
[d] Where some snubbing shots are fired.
[e] Including 6 sticks in 3 snubbing shots.

TABLE 3.—*Records of shots with permissible explosives in typical mines, showing data on method of placing, drilling, and loading the holes, amount of expolsive used, and coal produced*—Continued.

MINES IN FRANKLIN COUNTY—Continued.

MINE E—Continued.

Place where shots were fired.	Width of room or entry.	Height of coal.	Depth of undercutting.	Snubbing.		Position of hole.	Depth of hole.	Distance of hole from roof.	Distance of hole from rib.	Number of sticks of explosive used.	Length of fuse.	Depth of stemming.	Total sticks of explosive used.	Total cars of coal produced.	Total tons of coal produced.	Total pounds of explosives used.	Tons of coal produced per 25-pound box of explosive.
				Depth.	Height.												
Work in 8½-foot coal.[a]																	
Entry 7 R.:	*Ft. ins.*	*Ft. ins.*	*Ft. ins.*	*Ft. ins.*	*Ft. ins.*		*Ft. ins.*	*Ft. ins.*	*Ft. ins.*		*Ft. ins.*	*Ft. ins.*			*Tons. Cwt.*		
Room 13	27	8 6	5 6	3 0	2 0	L.	5 0	[b]1 0	2 6	4	5	3	13	12	55	6.5	212
						C.	5 0	[b]1 0	......	5	4	2 6					
						R.	5 0	[b]1 0	2 6	4	5	3					
Room 14	27 4	8 6	5 6	3 0	2 0	L.	5 1	[b]1 1	2 5	4	5	3	13	12	54 18	6.5	211
						C.	5 0	[b]1 1	......	5	4	2 6					
						R.	5 1	[b]1 1	2 6	4	5	3					
Room 16	26 8	8 8	5 6	3 0	2 0	L.	5 2	[b]1 2	2 0	4	5	3	13	12	54 10	6.5	210
						C.	5 2	[b]1 3	......	5	4	3					
						R.	5 2	[b]1 2	2 0	4	5	3					
Total for 3 entries	......	......	......	......	......	......	......	......	......	......	......	......	39	36	164 08	19.5	633
Average for work in 8½-foot coal	27 0	8 7	5 6	3 0	2 0	......	5 1	1 1	2 4	4.3	4 8	2 10	13	12	54 16	6.5	211
Grand average for room work in Mine E	28 3	9 4	5 6	4 4	2 7	......	5 1	1 2	2 0	3.3	5 4	3 6	13.6	14	59 16	6.8	220

MINE F.[c]

Room work.																	
Entry 12 off 8 SE.:																	
Room 1	27 0	6 6	6 6	2 0	1 6	L.	6 0	1 3	2 0	3	6 0	5 0	9½	12	44 2	4.75	232
						C.	6 0	1 3	....	3½	6 0	5 0					
						R.	6 0	1 3	2 0	3	6 0	5 0					
Room 2	27 2	6 5	6 6	2 0	1 6	L.	6 0	1 3	2 0	3	6 0	5 0	9½	12	43 10	4.75	229
						C.	6 0	1 3	....	3½	6 0	5 0					
						R.	6 0	1 3	2 0	3	6 0	5 0					
Entry 8 E S.:																	
Room 1	27 0	7 0	6 6	2 6	1 6	L.	6 0	1 6	1 6	3½	6 0	4 0	9	12	49 5	4.5	274
						C.	6 0	1 6	....	2	6 0	4 0					
						R.	6 0	1 6	1 6	3½	6 0	4 0					
Room 2	26 9	7 0	6 6	2 6	1 6	L.	6 0	1 6	1 6	3½	6 0	4 0	9	12	48 0	4.5	267
						C.	6 0	1 6	....	2	6 0	4 0					
						R.	6 0	1 6	1 7	3½	6 0	4 0					
Entry 1 E. off 2 NE.:																	
Room 1	27 4	7 1	6 6	2 0	1 0	L.	6 2	1 6	1 6	4	6 6	4 3	11	12	49 5	5.5	224
						C.	6 0	1 6	....	3	6 0	4 3					
						R.	6 2	1 6	1 6	4	6 6	4 3					
Room 2	27 0	7 0	6 6	2 0	1 3	L.	6 0	1 5	1 7	4	6 6	4 0	11	12	49 10	5.5	225
						C.	6 0	1 6	....	3	6 0	4 0					
						R.	6 1	1 6	1 8	4	6 6	4 0					
Total for six rooms	....	....	....	....	....	......	....	....	....	....	....	....	59	72	283 12	29.5	1,451
Average	27 1	6 10	6 6	2 2	1 5	......	6 0	1 5	1 8	3 3	6 1	4 5	9.8	12	47 05	4.9	242
Entries.[d]																	
Entry 1 S. off 4 E S	18 0	6 6	6 6	2 6	1 6	L.	6 0	1 3	1 6	3½	6 3	4 0	10	8	29 0	5.0	145
						C.	6 0	1 3	....	3	6 0	4 0					
						R.	6 0	1 3	1 6	3½	6 3	4 0					
Entry 2 S. off 4 E S	17 10	6 6	6 5	2 6	1 6	L.	6 0	1 2	1 6	3½	6 0	4 0	10	8	28 10	5.0	143
						C.	6 0	1 3	....	3	6 0	4 0					
						R.	6 0	1 2	1 6	3½	6 0	4 0					
Total	....	....	....	....	....	......	....	....	....	....	....	....	20	16	57 10	10.0	288
Average	17 11	6 6	6 5½	2 6	1 6	......	6 0	1 3	1 6	3⅓	6 1	4 0	10	8	28 15	5.0	144

[a] No snubbing shots fired.

[b] Holes parallel with rib and sloping up toward roof 1½ inches per foot.

[c] A Saline County mine. Shots are good average of the mine.

[d] Wide entries. Production practically proportional to width.

TABLE 4.—*Summary of data shown in Table 3, including cost of explosive per ton of coal produced.*

ROOM WORK.

Mine.	Number of rooms or entries observed.	Average width of room or entry.	Average height of coal.	Average depth of under-cutting.	Snubbing.		Average number of shots per room or entry.	Average depth of holes.	Average distance of holes from roof.	Average distance of rib holes from rib.	Average number of sticks of explosive per hole.	Average length of fuse per shot.[a]	Average depth of stemming.	Average total number of sticks of explosive per fall.	Average number of cars of coal produced per fall.	Average tonnage produced per fall.	Average number of tons produced per shot.	Average weight of explosive used per fall.	Average number of tons produced per 25-pound box of explosive.	Average cost of explosive per ton of coal produced.	Average cost of fuse and detonator per ton of coal produced.[b]
					Average depth.	Average height.															
		Ft. ins.	Ft. ins.	Ft. ins.	Ft. ins.	Ft. ins.		Ft. ins.	Ft. ins.	Ft. ins.		Ft. ins.	Ft. ins.			Tons cwt.	Tons cwt.	Lbs.			
A	21	27 0	7 11	6 2	2 6	1 10	3	6 0	1 1	2 3	3.5	8 E	3 0	10.6	13	53 01	17 14	5.9	226	$0.011	$0.0017
B	10	24 1	7 7	5 8	2 2	1 7	3	5 4	1 1	2 0	3.0	5 7	2 10	8.95	13	40 07	13 09	4.5	225	.011	.0028
C	6	28 0	7 7	5 6	2 4	1 6	3	5 0	1 2	2 0	4.4	5 5	2 7	13	13	42 08	14 02	6.8	157	.016	.0026
D	12	23 7	7 3	6 0	2 8	1 7	3	5 10	1 0	2 2	3.1	5 8	2 11	9.4	11.8	36 02	12 01	4.9	185	.013	.0032
E	7	28 3	9 4	5 6	4 4	2 7	5	5 1	1 2	2 0	3.3	5 4	3 6	13.6	14	59 16	11 19	6.8	220	.011	.0031
F	6	27 1	6 10	6 6	2 2	1 5	3	6 0	1 5	1 8	3.3	6 1	4 5	9.8	12	47 05	15 15	4.9	242	.010	.0026
Total for six mines	62	......	......	......	......	......	......	......	......	......	......	......	......	......	......	278 19	85 0	33.8	1,255	......	......
Average	......	26 4	7 9	5 11	2 8	1 9	3	5 6	1 2	2 0	3.4	5 7	3 2	10.9	12.8	46 10	14 03	5.6	209	.012	.0027

ENTRY WORK.[c]

Mine.	Number of rooms or entries observed.	Average width of room or entry.	Average height of coal.	Average depth of under-cutting.	Snubbing.		Average number of shots per room or entry.	Average depth of holes.	Average distance of holes from roof.	Average distance of rib holes from rib.	Average number of sticks of explosive per hole.	Average length of fuse per shot.[a]	Average depth of stemming.	Average total number of sticks of explosive per fall.	Average number of cars of coal produced per fall.	Average tonnage produced per fall.	Average number of tons produced per shot.	Average weight of explosive used per fall.	Average number of tons produced per 25-pound box of explosive.	Average cost of explosive per ton of coal produced.	Average cost of fuse and detonator per ton of coal produced.[b]
					Average depth.	Average height.															
A	2	11 5	6 11	5 9	2 3	2 0	2	5 6	1 0	1 5	4	8 E	2 8	8	5	17 19	9 0	4.5	100	$0.025	$0.0033
B	9	12 4	7 2	5 6	2 2	2 4	2	5 4	1 1	1 10	4	5 2	2 6	8.1	6.3	19 08	9 14	4.1	121	.020	.0037
C	4	12 0	7 4	5 6	2 2	1 6	2	5 1	1 0	1 6	4.4	5 7	2 3	8.9	6.0	18 14	9 07	4.55	103	.024	.0041
E	5	12 1	7 4	6 0	5 8	3 2	4	5 8	1 0	1 6	3	5 7	2 0	11	5	19 18	5 0	5.55	90	.027	.0076
Total for four mines	20	......	......	......	......	......	......	......	......	......	......	......	......	......	......	75 19	33 01	18.7	414	......	......
Average	......	12 0	7 2	5 8	3 1	2 3	2.5	5 5	1 0	1 7	3.85	5 5	2 4	9.0	5.6	19 00	8 05	4.7	104	.024	.0047

[a] Letter E signifies that electric detonator was used.
[b] With normal prices for fuse and detonators.
[c] Franklin County mines only.

PREPARATION OF THE PRIMING CARTRIDGE.

When detonators or blasting caps and fuse are used in preparing the priming cartridge, the following points are to be considered:

The detonator contains a highly sensitive substance, known as fulminate of mercury, and it should be handled with care.

The successful firing of the shot largely depends on careful and proper arrangement of the fuse and detonator.

The ingredients in fuse readily absorb moisture, also a part of the powder train may be lost from the open end, and therefore an inch or two of fuse should always be cut off the end of the roll before it is used.

The fuse should be cut off squarely with a sharp knife, the end being held in an upright position to prevent loss of powder. The end of the fuse should then be pushed gently up into the detonator until it touches the fulminate. It should not be twisted in the detonator, as the friction might be sufficient to explode the detonator.

The fulminate readily absorbs moisture; therefore the detonator should be kept in a moisture-proof container until it is to be used. The detonator should not be blown into with the breath, as moisture may thus be introduced.

The detonator should be crimped on the fuse with a proper crimper, providing a practically water-tight connection. Plate VI shows an improved type of crimper and the method of properly crimping the detonator to the fuse. The very common practice of crimping the detonator to the fuse with a knife is inefficient; crimping with the teeth is a dangerous practice. A satisfactory crimper may be bought for about 25 cents each, and as it is needed each day should be regarded as an indispensable part of the miner's equipment. It is to be regretted that so few are in use.

In Illinois mines the usual custom of preparing the primer is to punch two holes diagonally, one entirely through the cartridge of explosive and the other part way, usually with a wooden skewer. The fuse is then laced through the open diagonal hole in the cartridge[a] and the detonator end pushed into the other hole diagonally into the cartridge so that the detonator lies near the center of the cartridge, as shown in A, figure 13. The electric detonator is usually inserted in a hole punched diagonally into the side or end of the cartridge, and the wires are given a half hitch around the stick, as shown in B and C, figure 13.

By these methods the priming cartridges are easily and quickly prepared, and there is apparently some advantage in having the stemming[b] forced against the end of the explosive with less possibility of doubling back the fuse or wires and in preventing the detonator from being pulled from the cartridge during the tamping, as they serve to do. There are, however, several serious disadvantages in the use of these methods, and they are not regarded as the best practice for the following reasons: Care must be taken to see that the detonator lies near the center of the charge or the charge may not be detonated with full strength. If the explosive fills the drill hole tightly there is danger, when the cartridge is pushed into the hole, of breaking the insulation of the wires, or if fuse is used, the fuse projecting through the cartridge may be damaged when being inserted. With the fuse laced through the cartridge there is always the possibility that the explosive may be ignited by "side spitting" of the fuse, start to burn, and thus prevent complete detonation. If tamping be done too vigorously, with the electric detonator arranged as shown, the cartridge containing the electric detonator may be so expanded that the half hitch in the wire may form a tight knot and possibly give a short circuit or cause the wires to break.

---

[a] The Bureau of Mines does not recommend the lacing of fuse through the cartridge of explosive.

[b] In the publications of the Bureau of Mines, the word "stemming" is used to designate the material used to confine an explosive in a drill hole, and the word "tamping" is used to designate the act of ramming the stemming into the hole.

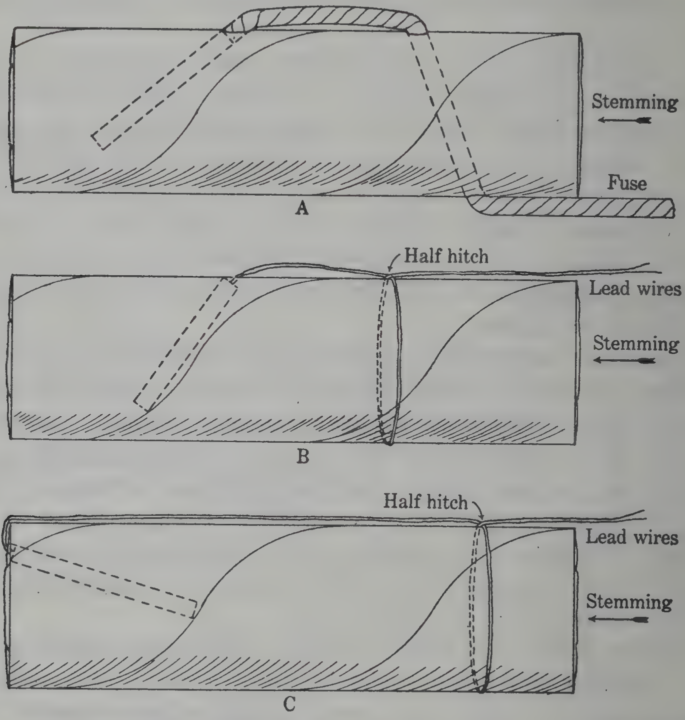
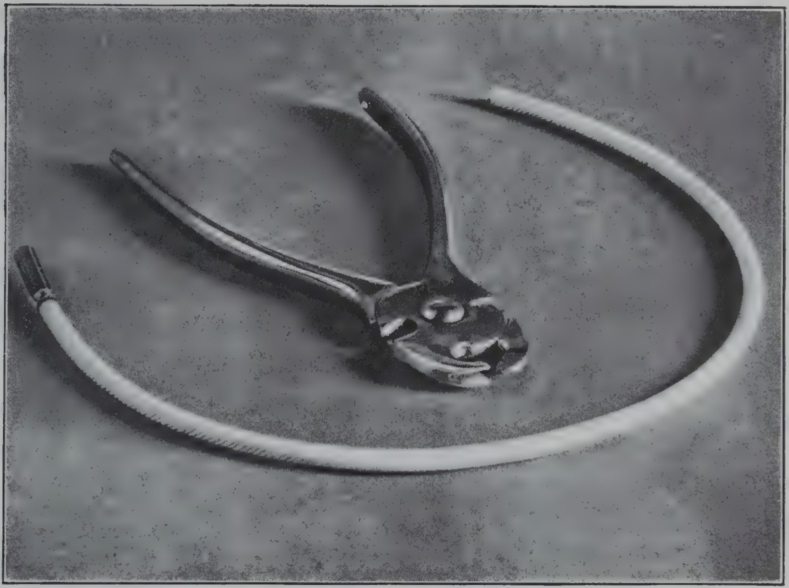
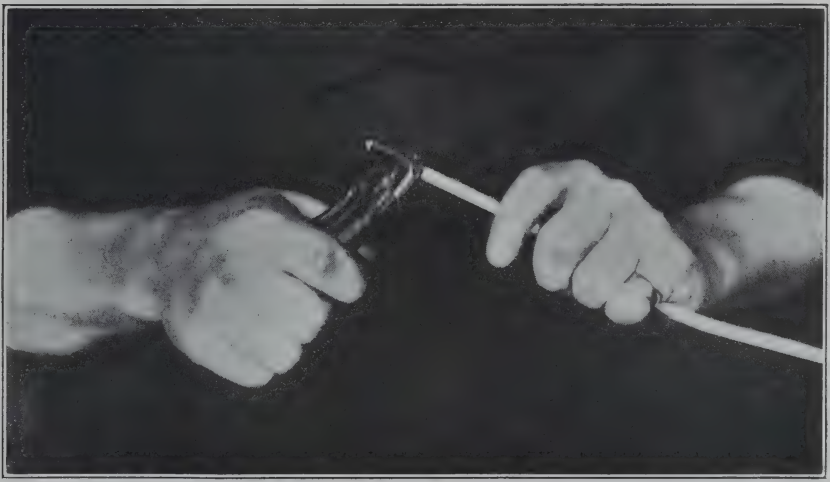


FIGURE 13.—Methods of arranging primers commonly used in the Illinois mines, not recommended. A, fuse laced through cartridge; B, electric detonator inserted in the side of cartridge and wires secured with half hitch; C, electric detonator inserted diagonally in end of cartridge and wires secured with half hitch.

Practices that are sometimes followed in Illinois and are recommended as being more efficient than the others are shown in figure 14, in



A. IMPROVED TYPE OF CRIMPER,



B. CRIMPING DETONATOR ON FUSE.

which the detonator with fuse is inserted in the end or side, and the electric detonator in the end of the cartridge, and tied in position as shown. The first two or three inches of the tamping material should be inserted loosely against the charge so that the more forceful tamping will not disturb the position of the detonator nor subject it to shock. These methods require that the miner provide himself with string to tie the detonator in place, but this important part of each day's work should be carefully attended to and sufficient time taken to perform the work with proper care. A simple and excellent method of using an electric detonator is shown in figure 15.

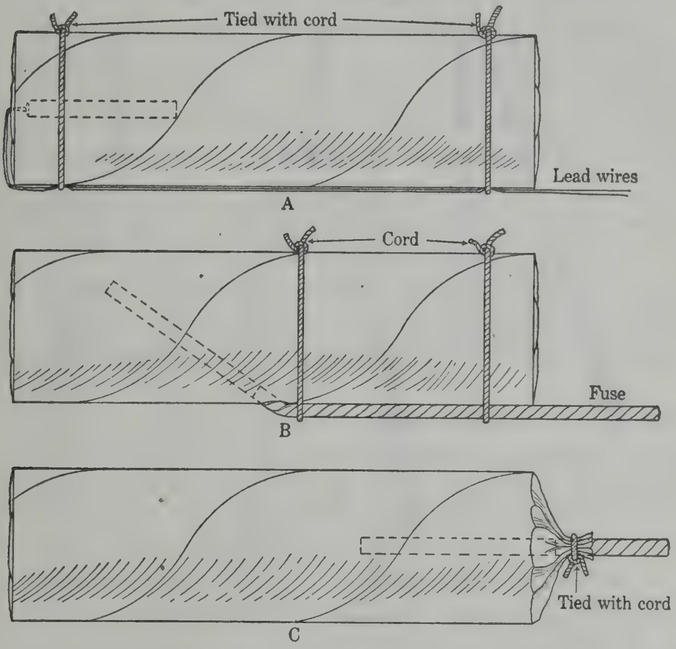


FIGURE 14.—Methods of arranging primers. A, electric detonator, wires tied with cord; B, fuse and detonator, detonator inserted in the side of cartridge and fuse tied to cartridge with cords; C, detonator inserted in end of cartridge and tied in with cord.

LOADING AND TAMPING THE HOLE.

Permissible explosives in cartridges 1¾ by 6 inches or 1¾ by 7 inches in size and weighing approximately one-half pound have been found to be the most satisfactory in Illinois and are used exclusively. The use of this diameter of cartridge, which is larger than ordinarily used in coal mining elsewhere, places a sufficient quantity of explosive at the back of the drill hole to do the required work, without the cartridges being broken. The miner usually carefully scrapes all drill dust from the hole before he inserts the cartridges, so that no material can lodge between them and prevent close contact. The cartridges are placed in the drill hole in their original wrappers, usually without the paper ends being torn off, and are pushed back with the tamping bar. Some miners place the primer, containing the cap, in last, others place it in the middle when using three sticks. It is usually the last or next to the last cartridge put in.

Clay stemming is generally used and tamping is accomplished by means of a heavy iron bar, copper tipped.[a] The stemming is usually made up in paper cartridges, called "dummies," about 2 inches in diameter and 12 to 15 inches long. Generally speaking, 3 feet of stemming is sufficient for satisfactory results with the usual charge in a 6-foot hole, but sometimes the drill hole is directly above and parallel to a hard "sulphur" or "rock" band, and it takes more stemming to prevent the charge from blowing out. The amount of stemming should be sufficient not only for ordinary conditions but for extraordinary conditions, and therefore the stemming should always extend to the mouth of the drill hole. The State law in regard to tamping reads as follows: [b]

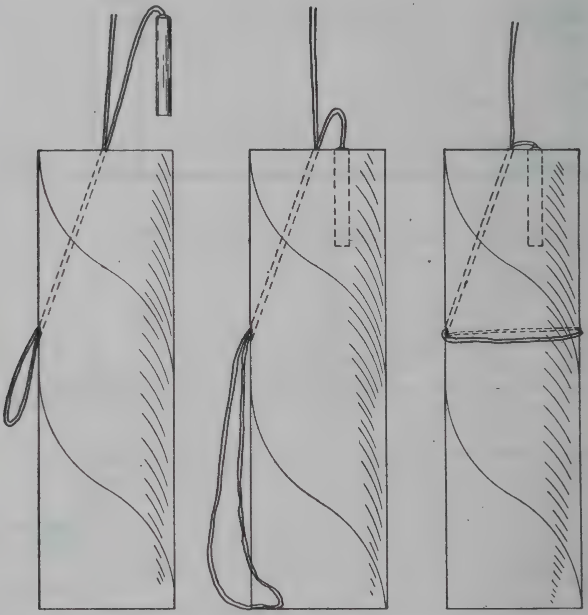


FIGURE 15.—Another method of inserting electric detonator in primer.

Tamping.—Every blasting hole shall be tamped full from the explosive to the mouth of the hole, and no coal dust or any material that is inflammable or that may create a spark, whether the same shall be wet or dry, shall be used for tamping.

---

[a] The Bureau of Mines recommends the use of a wooden tamping bar.

[b] Coal-mining laws of Illinois, sec. 19 (*i*).

Although the law thus decrees that only noninflammable material shall be used as stemming, experience has shown that where such material can not be had conveniently some of the men will use "bug dust," or drill dust, unless close discipline is maintained, and some shot firers have no objections to its use. In every mine in the district clay is obtainable from the floor. Sometimes it is obtained with difficulty, but the practical miners know that by pouring some water or coffee from their dinner pails on a convenient spot the clay overnight becomes moist and breaks up easily; and thereafter it is a simple matter to obtain all necessary clay for tamping by occasional dampening. Where clay is not obtainable from the floor, no doubt the operator would be willing to send to convenient points in the mine suitable surface clay or dirt. Clay, in addition to being the more efficient material for holding the charge, tends to damp the flame in the event of a blown-out shot. The dangers of coal-dust stemming have been shown in tests with black blasting powder at the Pittsburgh experiment station of the Bureau of Mines; the use of coal-dust stemming lengthened the flame of a blown-out shot 50 to 60 feet.[a]

There is no defense for the use of coal dust for stemming. Several times when its use was called to the attention of the miners a majority of them strongly denounced the practice. A number of the State inspectors' reports recommend that the use of drillings be discontinued and that clay be used.

Care should be taken in tamping. The heavy iron bar commonly used should be abandoned, as it is dangerous, and a wooden tamping bar substituted. It is possible to strike a spark from a lump of pyrite, or "sulphur," with a metal rod, even of copper. The wooden tamping bar is much safer, is less liable to injure the fuse or detonator wires, and is sufficiently heavy to insure efficient tamping.

If wet holes are encountered, they are usually left uncharged and the shot firer does the charging and tamping; otherwise all shots are tamped by the miner. In the event that he quits work before the shot firer makes his rounds, the miner takes a piece of cartridge paper and marks on it the figure indicating the number of shots prepared in his room and posts it near the room mouth for the information of the shot firer. In some mines two brands of permissible explosives are used, and in a few instances both brands have been used in a single drill hole. This practice is not prevalent and has been done without understanding the danger of the practice, when a miner had but one or two sticks of a certain brand left and borrowed some of another brand from a fellow miner, or changed to a new brand. A fire may result from the use of two different brands in the same shot.

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[a] Rice, G. S., The explosibility of coal dust: Bull. 20, Bureau of Mines, 1911, pp. 53–54.

METHODS OF FIRING SHOTS.

Relative to shot firing in Illinois mines, the State law in part reads:[a]

> In all mines in this State where coal is blasted, and where more than 2 pounds of powder is used for any one blast; and also, in all mines in this State where gas is generated in dangerous quantities, a sufficient number of practical, experienced miners, to be designated as shot firers, shall be employed by the company, and at its expense, whose duty it shall be to inspect and do all the firing of all blasts, prepared in a practical, workmanlike manner, in said mine or mines.

Shot firers are employed in all the mines using permissible explosives, from two to six shot firers being employed at each mine. They enter the mine at 1.30 to 2 p. m. and examine the shots to be fired, noting the place in the mine and the number of the shots. After inspection, the shot firers return to the shaft bottom. Later, after the miners have all left the mine, they fire the shots, completing their work in two and one-half to six hours. In the inspection of shots they work singly; when firing they work in pairs, this being in accordance with the working agreement between the operators and miners.[b] Firing the three shots in a room at the same time is commonly practiced, the center, or "buster," shot having a shorter fuse than the two rib shots. When firing with fuse and detonator, the fuses are all lighted at the same time; with battery and electric detonator, the shots are fired one at a time.

As shown in Table 1, in all but two mines the shots are fired by fuse and No. 6 detonators. In two mines electric detonators and battery are used. In firing by electricity the shot firers carry about 110 feet of duplex No. 14 cable and a firing battery that can fire one to four holes. This system offers many advantages as regards safety and efficiency. Some of these advantages are as follows:

When firing is done by detonator and fuse, the interval of time between the exploding of the "buster" shot and the second shot is often not more than a second or two. The first shot will always stir up a certain amount of fine dust and in a gaseous mine may liberate some gas, and if the second shot contains an excessive charge of explosive and is poorly and insufficiently tamped, as sometimes happens in mines even under the closest inspection, a "windy" shot may result. With electric firing such a condition could not arise. There can be no "hang fires" and there are possibly fewer misfires, as the electric detonator gives better protection against wet holes, not being easily affected by moisture. In storage and use, the electric detonators are much more satisfactory from practically every point of view than fuse and detonators. The electric detonators are prepared ready for use, and can be tested before being used by means of a galvanometer; the objections to crimping are overcome; they are not so liable to be spilled or lost as the ordinary detonator; a better check can be made on the grade of detonators used and the use of detonators of proper strength more easily enforced; their use eliminates flame, as in lighting fuse or as in the "side spitting" of fuse, and provides for firing shots in a desired order. If the "buster" shot fails, the rib shots need not be fired. The method is safer and more satisfactory and conforms more fully with the requirements for the use of permissible explosives.

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[a] See pp. 97 to 99 for State law and working agreement between operators and miners relative to firing of shots.

[b] See pp. 97–98.

The cost of electric detonators with 8-foot iron-wire leads, at normal prices, is 3 cents to the miner. The cost of fuse is about one-half cent per foot; detonators cost 1 cent each. The average shot requires about 5 feet of fuse; hence the cost to the miner, with the electric detonators, is perhaps slightly less than when fuse is used.

Shot firers' wages cost the operator about $0.0075 per ton of coal mined in four typical mines in Franklin County. For one Montgomery County mine the cost is about $0.008 and for one Saline County mine $0.0075. The cost per ton for shot firing in mines using battery and electric detonators is approximately the same as in mines employing shot firers, averaging between $0.007 and $0.0075 per ton of coal. The shot firers are paid for eight hours' work at a uniform rate of 58⅞ cents per hour.

NUMBER OF SHOTS FIRED.

The total number of shots fired per shift in the 19 mines listed in Table 1 is about 4,400; the daily average per mine is 231. The approximate number of shots fired nightly by each shot firer for "fuse and detonator" mines is 60; for "battery and electric detonator" mines, 56. As required by the State law, a notice is posted at each mine at the end of each shift showing the number of shots fired, the number not fired and reasons therefor, and the number of misfires. The form following is used:

SHOT FIRERS NOTICE.

(To be posted in a conspicuous place at the mine immediately after the completion of the work of firing shots—Section 2, Shot Firers Law.)

Name of owner or operator of mine: ——— *Coal Mining Co.* No..........
We, the undersigned shot firers, have this..........day of..................191..
fired............shots in this mine. We have also refused to fire............shots.

The shots we have refused to fire, and our reasons for not firing same, are as follows:

LOCATION.	REASONS FOR NOT FIRING SHOTS.

SHOTS FAILING TO EXPLODE.

LOCATION.	LOCATION.

..............Shot Firer.	..............Shot Firer.	..............Shot Firer.
..............Shot Firer.	..............Shot Firer.	..............Shot Firer.
..............Shot Firer.	..............Shot Firer.	..............Shot Firer.

From the records examined at the various mines it was evident that some shot firers required more strict adherence by the miners to rules than others. The reasons for refusals to fire shots at one mine during a period of two months were noted as follows: Six, not properly snubbed; four, "bug dust" not loaded out; four, crosscut in entry not through;[a] two, car in the way.

MISFIRES.

The proportion of misfires in the mines is considerably less than 1 per cent. The records at one mine show only four misfires in a period of three months and the firing of upwards of 10,000 shots. At another mine three misfires occurred in 3,500 shots; at another, four in four months, or 25,000 shots. The usual impression is that rarely more than two misfires occur in one night at any one mine. Some data on misfires at two mines are given in the following tables:

---

[a] The mining law states that not more than three shots shall be exploded at one shooting time ahead of the last open crosscut. See Appendix, p. 99.

Record from one mine for period of two months, detonators and fuse used:

Date.	Number of shots fired.	Misfires.	Remarks.
1915.			
January	4,821	5	104,296 tons of coal was produced during this period, or 8,000 tons for each misfire.
February	3,990	8	
Total	8,811	13	

Percentage of misfires, 0.15 per cent.

Data on shots fired during 20 months at one mine, using electric detonators and battery system.

Date.	Number of shots fired.	Number of misfires.
1914.		
July	5,498	21
August	7,525	5
September	7,073	10
October	6,936	10
November	6,443	5
December	6,716	14
1915.		
January	7,024	12
February	3,380	7
March	4,187	6
April	3,832	5
May	1,878	1
June	3,059	5
July	4,227	9
August	4,146	8
September	6,046	19
October	7,558	17
November	5,327	14
December	7,497	19
1916.		
January	6,755	20
February	7,459	14
Total	112,566	221

Remarks.—Percentage of misfires, 0.2 per cent. As shots are fired one at a time by battery, this system affords an actual check on the number of misfires, and this record is much more accurate than records with fuse and detonator system. In one instance three shots misfired in one room the same night; in another, two. The following reasons for refusals to fire shots are given in the shot firers' records for this 20-month period: Top "working," 44; "bug dust" not loaded, 28; too far ahead of air, 16; car in way at face, 14; not snubbed, 8; place falling in, 6; too many shots ahead of air, 4; "buster" shot failed, 4; hole "on the solid," 3; retamped holes previously fired, 3; machine in way, 3; explosive in "buster" hole took fire and burned, remaining holes not fired, 1; detonator wire broke, 1; no primer made, 1.

PREVENTION OF MISFIRES.

The prevention of misfires is a matter of interest to the miner, both from safety and economy, and the subject should receive his careful consideration. The explosive with which he is supplied should be in good condition and he should take pains to keep it so. It is readily understood that with all the material in good condition and the shot properly arranged, misfires will seldom happen. As previously discussed, proper storage of fuse, detonators, and explosive, careful preparation of the primer, with use of crimper if fuse and detonator are used, and proper charging of the drill hole, are essential.

A few examples of causes of misfires investigated during the past year are as follows: A miner had been carrying detonators loose in his pockets. Possibly some tobacco or dust lodged on the fulminate of the detonator and prevented the "spit" of the fuse from reaching and exploding it. Such practice is inefficient and dangerous. In another instance a shot that misfired had been charged two hours previously. The detonator had been crimped with a knife and moisture had seeped in. In another the fuse was broken during tamping.

Careless storing of fuse before it is used accounts for many misfires and hangfires, but a greater number result from carelessness in handling the fuse when it is inserted in the drill hole. The large copper-tipped iron tamping bars ordinarily used in Illinois mines are heavy, and the fuse is often crushed between the edge of the heavy bar and the sides of the drill hole. Rough handling may break the powder train or so damage the fuse that water can readily enter it if the hole or the stemming is damp, or the end of the fuse may lose part of the powder train and give a chance for misfires. The double-tape fuse is much better than cheaper grades because it will withstand more severe handling and is not so easily crushed.

Sometimes the end of the fuse, if damp from being exposed to the mine air or from lying on the damp bottom for a considerable time, can be inserted in the detonator only with difficulty, and the miner is unable to get it closer to the fulminate than about one-half inch. In that event the copper walls of the capsule containing the fulminate might absorb enough heat from the flame so that it would not ignite the fulminate. Fuse in good condition will have a "spit" at least 1¼ inches in length, but under the conditions mentioned—that is, damp fuse and the end of the fuse one-half inch from the fulminate composition—the "spit" may be reduced to a quarter of an inch or less. Even if the end which has been exposed to moisture is left for the shot firer, it may "spit" when lighted, burn for an inch or so, and go out, thus giving a missed shot.

In two different instances of shot failures in the same room, the stemming was blown out but the charge did not explode, indicating that old explosive or weak detonators had been used, as a box of detonators without a cover was found in this room.

An instance was noted in which fuse had been stored for a long period in a warm, poorly ventilated magazine, and the heat had caused the tar composition used in the manufacture of the fuse to run, giving a black color to the fuse. Much handling of fuse of this character might cause the tar composition to get in the powder train and cause a misfire.

COSTS OF PERMISSIBLE EXPLOSIVES PER TON OF COAL, AND SIZES OF COAL PRODUCED.

Table 1 shows that the highest average production of coal per 25-pound box of explosive for a period of one year in any of the mines listed, including all room and entry work, is 215 tons; the lowest is 107 tons. As the mines listed include mines in various stages of development and others fully developed, a fair average can be obtained. The average production for 18 mines is 147 tons per 25-pound box of explosive. The average cost of explosive per ton of coal produced, with explosive selling at \$2.45 per box, is therefore \$2.45 ÷ 147 = 1.7 cents, the cost varying from the lowest figure, \$2.45 ÷ 215 = 1.14 cents, to the highest, \$2.45 ÷ 107 = 2.3 cents. To these figures must be added the cost of fuse and detonators per ton of coal, which averages 0.25 cent for fuse and 0.1 cent for detonators. These averages for fuse and detonators are obtained from data on five typical mines, as follows:

Data on number of detonators used and production at five mines for period of one year.

Mine.	Year ending—	Number of detonators used.	Number of tons produced.
No. 1	Mar. 31, 1915	36,300	420,612
No. 2	do	65,600	637,359
No. 3	Dec. 31, 1914	46,700	563,127
No. 4	do	21,300	291,351
No. 5	Mar. 31, 1915	50,300	528,930
Total		220,200	2,441,379

Production per detonator used	tons	11
Production per foot of fuse used	do	2
Average length of fuse per detonator used	feet	5½
Average cost of detonators per ton of coal (detonators at 1 cent each)		\$0.0010
Average cost of fuse per ton of coal		.0025
		.0035

Adding to this the average cost of explosive per ton of coal produced, 0.017 cent, gives an average total cost of \$0.0205.

In one mine using electric shot firing, during a period of 14 months ended June 30, 1915, 50,100 electric detonators were used. The production was 858,365 tons; the production per electric detonator used was 17 tons; and the average cost of electric detonators per ton of coal produced, \$0.0018. On the basis of these figures, the cost for electric detonators is \$0.0018, as compared with fuse and detonator at \$0.0035. The use of electric detonators is therefore cheaper for the miner.[a]

The foregoing figures include general mine averages. Data on results of shots, taken at random from typical mines, in rooms and entries are given in Table 3. This table shows that the average cost of fuse and detonators per ton of coal in rooms with normal prices prevailing, was \$0.002; with electric detonators the cost was \$0.0017.

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[a] The cost of detonators and electric detonators increased about 50 per cent in 1916 through the increased demand for explosives.

In entry work the average cost for fuse and detonators at two mines was $0.0039, and for electric detonators at one mine was $0.0033. This table also shows that the average production was 209 tons of coal per 25-pound box of explosives in rooms, or the cost of explosives per ton of coal was 1.1 cents. In some rooms a production of 300 tons per 25-pound box of explosive was obtained. The average production in entries was 104 tons per 25-pound box, the explosive cost per ton of coal being 2.4 cents. It is felt that on the average the miner in rooms can easily obtain 200 tons of coal per 25-pound box of explosive at a cost of less than 1.5 cents per ton of coal produced, including fuse and detonators.

Additional data on the cost of explosives per ton of coal produced from a test with two brands of permissible explosives at one mine are as follows:

Results of tests of two permissible explosives at one mine.

Permissible explosive used.	Number of places shot.	Average depth of holes.	Explosive used.	Total cost.	Coal produced.	Cost per ton.	Coal produced per 25-pound box explosive.
		Ft. in.	*Pounds.*		*Tons.*		*Tons.*
No. 1	4	5 10	19.9	$1.95	145.15	$0.0134	182
No. 2	4	5 11	18.5	1.81	147.40	.0123	200
Average						.0128	191

The percentages of different sizes of coal produced with the use of permissible explosives at ten mines in Franklin county, the coal being screened over shaking screens with round holes, were as follows:

Sizes of coal produced with permissible explosives in 10 mines.

Mine No.	Lump, 6 inches in diameter.	Egg, 3 to 6 inches in diameter.	Nut, 2 to 3 inches in diameter.	Screenings, 2 inches in diameter.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
1	18.22	19.77	10.96	51.05
2	22.08	20.40	12.52	45.00
3	18.00	22.15	10.50	49.35
4	22.00	14.00	16.00	48.00
5	17.00	23.00	12.00	48.00
6	27.34	20.29	11.91	40.46
7	24.14	20.67	12.60	42.59
8	22.05	21.62	11.86	44.47
9	23.44	20.43	9.28	46.85
10	21.73	17.42	10.65	50.20
Average	21.60	19.97	11.83	46.60

COMPARISONS WITH USE OF BLACK BLASTING POWDER IN ILLINOIS MINES.

COSTS OF EXPLOSIVE PER TON.

Comparative data on the cost of explosives per ton of coal and the sizes of coal produced from all the mines were not obtainable, owing to the fact that the different mines were using both permissible explosives and black blasting powder, or were shooting off the solid and also mining by machines at the same time. Some mines changed from shooting off the solid with black blasting powder to machine mining and permissible explosives; other mines have used permissible explosives exclusively and have no data on black blasting powder. Changes in methods of preparation of coal have also been made.

A few typical comparisons of the relative productive values of black blasting powder and permissible explosives are as follows:

Data showing comparative production of coal with equal amounts of black blasting powder and permissible explosive at one mine.

BLACK BLASTING POWDER.

Month.	Coal produced, tons.	Number of 25-pound kegs of black blasting powder used.	Tons of coal produced per 25-pound keg of black blasting powder.
October, 1908	38,746	430	90.10
November, 1908	30,270	363	83.38
Total	69,016	793	87.03

PERMISSIBLE EXPLOSIVE.

Month.	Coal produced, tons.	Number of 25-pound boxes of permissible explosive used.	Tons of coal produced per 25-pound box of permissible explosive.
October, 1910	49,706	286	173.79
November, 1910	48,612	274	177.41
Total	98,318	560	175.55

The above figures show a production of two tons to one in favor of permissible explosives with the use of equal amounts of explosive.

The average production per unit of explosive for a period of one year at five mines which changed from black blasting powder to permissible explosives is as follows:

Average production at five mines with black blasting powder and permissible explosives.

Mine No.	Tons previously produced per 25-pound keg of black blasting powder.	Tons produced per 25-pound box of permissible explosive.
1	90	130
2	100	202
3	85	128
4	68	107
5	131	215
Average	95	156
Ratio	1	1.64

Explosives cost per ton of coal produced with black blasting powder at $1.75 per 25-pound keg	$0.0184
Explosives cost (including detonators) per ton of coal produced with permissible explosive at $2.45 per 25-pound box	.0167

The above data include mines in Franklin, Saline, and Montgomery Counties and are representative of the comparative production by black blasting powder and permissible explosives in mines in which the physical character of the coal differs considerably.

Data available from an early test in determining the price to miners for permissible explosives in Franklin County mines in 1910 are given as follows:

Data on shots with black blasting powder and a permissible explosive.

Place where shot was fired.		Shots with black blasting powder.				Shots with a permissible explosive.			
Entry.	Room.	Number of shots.	Quantity of explosive.		Coal produced.	Number of shots.	Quantity of explosive.		Coal produced.
			Lbs.	*oz.*	*Tons.*		*Lbs.*	*oz.*	*Tons.*
5 NW	5	3	4	13	31	3	3	14	22
4 SW	18	3	6	7	43	3	2	11½	32
4 SW	25	3	5	8	36	3	4	5½	38
2 NW	3	3	7	4	39	3	3	8	41
2 NW	4	3	6	10	38	3	3	13	40
Total		15	30	10	187	15	18	4	173
Average per shot		1	2	⅔	12.5	1	1	3.5	11.5
Coal produced per pound of explosive					6.2				9.5
Tons of coal per 25-pounds of explosive					155.0				237.5

Ratio of production per pound of explosive: Black powder, 1; permissible explosive, 1.53. If the shots in room 5, entry 5 NW, in which the permissible explosive did not produce its full amount of coal, be eliminated, then for 12 shots in four rooms the relative production is—black powder 1, permissible explosive 1.75.

The records show that in three instances some work was necessary to obtain all the coal from the shots with the permissible explosive, but on the whole the results were satisfactory.

The results of a test at one mine with black powder and three brands of permissible explosives by the joint State powder commission were as follows:

Results of tests with black blasting powder and three brands of permissible explosives.

Explosive.	Number of places shot.	Quantity of explosive used.	Number of squibs used.	Length of fuse used.	Number of detonators used.	Total cost of explosive.	Amount of coal produced.	Cost per ton of coal.	Production per 25-pound box explosive.
		Pounds.		*Feet.*			*Tons.*		*Tons.*
Black blasting powder	4	29.50	12	....	....	$2.08	191–3	$0.0108	162
Permissible explosive No. 1	12	54.75	None.	233	35	6.83	525–	.0130	240
Permissible explosive No. 2	15	67.25	None.	240	42	8.21	624–	.0131	232
Permissible explosive No. 3	15	72.75	None.	250	44	8.82	629–	.0140	216

The average production with the three permissible explosives was 228 tons per 25-pound box. The ratio of production was: Black powder, 1; permissible explosive, 1.4. This ratio has been considerably improved since permissible explosives came into general use at this mine.

Data from the annual coal reports of the State mining board show an average production of 116 tons of coal per 25-pound keg of black blasting powder for a three-year period at the above mine, including rooms and entries. The average production per 25-pound box of permissible explosives is 215 tons. The ratio of production per unit of black blasting powder to permissible explosives is therefore 1 : 1.85.

A test by the powder commission at another mine gave the following results:

Results of tests at another mine.

Explosive and place.	Number of places shot.	Average length of hole.		Quantity of explosive used.		Length of fuse used.		Tons produced.		Cost per ton.
		Ft.	*in.*	*Lb.*	*oz.*	*Ft.*	*in.*	*Tons.*	*cwt.*	
Black blasting powder:										
Rooms	5	5	5	57	5	72	0	243	19	[a] $0.0164
Entries	4	5	6	36	11	34	10	71	8	[a] .0370
Permissible explosive:										
Rooms	5	5	5	32	0	79	6	220	2	[b] .0152
Entries	4	5	8	16	15	44	10	62	15	[c] .0297

[a] Does not include cost of fuse.
[b] Add $\frac{1}{15}$ cent per ton for detonators.
[c] Add $\frac{1}{8}$ cent per ton for detonators.

Price of black blasting powder, $1.75 per 25-pound keg; permissible explosive, $2.45 per 25-pound box. Ratio of production with black blasting powder to production with permissible explosive: In rooms, 1 : 1.6; in entries, 1 : 1.9.

The figures of the test show that the cost for explosives per ton of coal produced in entries is practically double that in rooms. The previous average at this mine was 68 tons per 25-pound keg of black blasting powder. The present average with the permissible explosive used is 107 tons per 25-pound box. The permissible explosives, therefore, produce 1.6 times as much coal per unit as black blasting powder, which closely bears out the figures of the first test.

With black blasting powder, at $1.75 per 25-pound keg, and permissible explosive, at $2.45 per 25-pound box, permissible explosive is considerably cheaper for the miner on the basis of cost of explosives and detonators [a] per ton of coal produced.

Data by Andros [b] give for 43 machine mines in Illinois using black blasting powder, a powder cost of 2.1 cents per ton of coal; and for 34 mines in which shooting from the solid is practiced, a powder cost of 8.3 cents per ton of coal.

RELATIVE SIZES OF COAL.

A few typical comparisons of the sizes of coal produced, from data obtained at various mines, are as follows:

The sizes of coal produced in one mine for two consecutive months in 1912 with black blasting powder are as follows:

Production with black blasting powder for two months in 1914.

Size of coal.	Amount produced during—		Average.
	First month.	Second month.	
	Per cent.	*Per cent.*	*Per cent.*
6-inch lump	20	19	19.5
3 to 6 inch egg	22	19	20.5
2 to 3 inch nut	7	14	10.5
2-inch screenings	51	48	49.5
Total	100	100	100.0

The production in the same mine for three consecutive months with permissible explosives in 1914 was as follows:

Production with permissible explosives for three months in 1914.

Size of coal.	Amount produced during—			Average.
	First month.	Second month.	Third month.	
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
6-inch lump	20	19	17	18.7
3 to 6 inch egg	24	26	24	24.7
2 to 3 inch nut	6	5	9	6.6
2-inch screenings	50	50	50	50.0
Total	100	100	100	100.0

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[a] The cost of detonators, as shown on p. 67, is approximately 0.1 cent per ton of coal produced, and is very low because a large production of coal is gained per shot. The average cost in some rooms is not more than 0.07 cent per ton of coal produced.

[b] Andros, S. O., Coal Mining in Illinois, Bull. 13, Coal Mining Investigations, 1915, pp. 116, 122.

This shows that comparatively as good results are obtained with permissible explosives and that the slight decrease in the proportion of 6-inch lump is offset by increase in the egg sizes with little increase in screenings.

The results at another mine were as follows:

Relative sizes obtained at one mine.

	Lump, 6-inch.	Egg, 1¼ to 6 inch.	Screenings, 1¼-inch.
Previous average yield with black blasting powder	13.35	46.88	39.77
Yield with permissible explosives for week ending Aug. 15, 1914	12.49	47.94	39.57
Yield with permissible explosives for week ending Dec. 12, 1914	12.04	47.05	40.91
Yield with permissible explosives for period of Jan. 1–15, 1915	11.71	46.32	41.97
Average for 4 weeks with permissible explosives	11.99	46.91	41.10

This showing is favorable for permissible explosives. The results at another mine during the last year of using black blasting powder and the first year of using permissible explosives were as follows:

Comparative results for periods of one year each.

Size of coal.	Last year of using black powder.	First year of using permissible.
	Per cent.	*Per cent.*
Lump, 6-inch	24.19	20.41
Egg, 3 to 6 inch	19.28	21.29
Nut, 2 to 3 inch	16.50	12.88
Screenings, 2-inch	40.03	45.42

The comparison above represents perhaps the maximum increase in screenings due directly to the use of permissible explosives. A small amount of pillar coal is included in the percentages for permissible explosives.

One of the latest mines in which the use of permissible explosives has been substituted for black blasting powder reports excellent results both in cost of explosive to the miner and sizes of coal produced. The cost of explosives to the miner has been reduced practically 50 per cent, and the proportion of larger sizes of coal has been increased. Records kept for a two-month period show a decrease of 3½ per cent in the amount of 1¼-inch screenings.

It is generally agreed that the use of permissible explosives may give slightly more screenings than the use of black blasting powder, but the results obtained have been convincing proof that under favorable conditions the increase in proportion of screenings from using permissible explosives can be kept at a low figure. The increase at the majority of these mines ranges from nothing to 1 or 2 per cent, with a maximum of 5 per cent. As the miner is paid on the mine-run basis, he has no special incentive to produce lump coal; hence these figures may be accepted as the results obtained from the use of permissible explosives under regular working conditions without an attempt to obtain a maximum amount of lump coal.

THE DEMAND FOR THE DIFFERENT SIZES.

The preparation of a great number of sizes of coal is necessary at Illinois mines to meet the market demands. Most of the mines where permissible explosives are used are equipped to load eight to ten sizes of coal. At one mine equipment was provided to load 17 sizes of coal, as shown in the following table:

Data on equipment for loading 17 sizes of coal.

Number of combination.	Track 1.		Track 2.		Track 3.		Track 4.	
	Kind of coal.	Size of coal.	Kind of coal.	Size of coal.	Kind of coal.	Size of coal.	Kind of coal.	Size of coal.
		Inches.		*Inches.*		*Inches.*		*Inches.*
1	Lump	¾					Screenings.	¾
2	do	2			Nut	¾ by 2	do	¾
3	do	6	Egg	2 by 6	do	¾ by 2	do	¾
4	do	1¼					do	1¼
5	do	2			Nut	1¼ by 2	do	1¼
6	do	6	Egg	2 by 6	do	1¼ by 2	do	1¼
7	do	3			do	1¼ by 3	do	1¼
8	do	6	Egg	3 by 6	do	1¼ by 3	do	1¼
9	do	6	do	1¼ by 6			do	1¼
10	do	2					do	2
11	do	3			Nut	2 by 3	do	2
12	do	6	Egg	3 by 6	do	2 by 3	do	2
13	do	3			Screenings.	3		
14	do	6	Egg	3 by 6	do	3		
15	do	6	Mine run	6				

Very little run-of-mine coal is shipped from the mines. As noted on page 68 the proportion of lump coal and screenings produced at 10 of the mines under discussion averages 53.4 per cent lump and 46.6 per cent of 2-inch screenings. The demand for these sizes is variable. During a part of the year the markets require the larger sizes of coal, which command a higher price than screenings; therefore, it is of interest to the operator to produce at such times as large a percentage as possible of these larger sizes. The greatest demand for lump coal probably comes in the late summer and in the fall and winter, with a consequent rise in prices during these periods. It is, however, necessary to produce screenings in the proportion noted above whenever lump coal is produced; therefore, the price of screenings tends to be lower during the periods when the price of lump coal is highest.

The demand for screenings, which comes largely from steam power plants, is more nearly constant during the whole year; consequently the mines, to meet the demand for screenings, must in the spring and summer months produce lump coal for which there is little demand. This may necessitate for certain periods crushing of the lump coal produced. During the spring of 1915 one company crushed 400 tons of 6-inch lump daily for a time, and other companies are considering the installation of machinery for crushing coal during the spring and summer months. During the previous winter, however, some companies were forced to store their screenings in piles at the mines when the greatest demand was for the larger sizes; then when the demand for lump coal fell off and that for screenings continued steady, steam shovels were employed to load the screenings, while thousands of tons of lump loaded on cars waited for a market.

In this connection Weeks states [a] that—

> Under present conditions (spring of 1915) it matters but little whether we are able to produce 20 or 40 per cent of screenings or 80 or 60 per cent of larger sizes; there arises daily the necessity to reduce prices on one or more sizes to prevent congestion at the mines.

The demand for small prepared coal and for screenings has been increasing year by year. This demand and the high price obtained for the nut sizes, which are taken from the screenings, as a domestic fuel is at some of these mines a factor that increases the relative value of the fine sizes, greatly prolongs the period in which it may pay to produce the smaller coal, and assists to maintain a better balance in the value of the whole product. Owing to these varying demands it is difficult to form a correct basis for computing how much a possible small increase in screenings from the use of permissible explosives might effect the average value of the mine output.

Taking the average price of lump coal over 2-inch screens as $1.48 and the average price of 2-inch screenings as $0.73, as representative of Franklin County market prices [b] for the years 1913 and 1914, the difference in value per ton is $0.75, and consequently each increase of 1 per cent of screenings decreases the value of the product, in terms of mine-run coal, three-fourths of a cent per ton.

Although it is desired that the largest possible production of the larger sizes be maintained, the feeling prevails among the operators that the advantages of permissible explosives make their use economical even with a slight increase in the proportion of screenings. Hence the present problems do not include considerations of a return to the use of black blasting powder, but possible ways and means of improving the results obtained with permissible explosives. Such items are discussed in a following chapter.

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[a] Weeks, H. W., The influence of size on the cost of making steam: The Black Diamond, Mar. 20, 1915, p. 233.

[b] Holbrook, E. A., Dry preparation of bituminous coal at Illinois mines: Bull. 88, Eng. Exp. Station, University of Illinois, 1916, p. 76.

FACTORS AFFECTING COST OF EXPLOSIVES PER TON OF COAL AND SIZES OF COAL PRODUCED.

There are a number of factors that influence the cost of explosives per ton of coal and the sizes of coal produced. It is difficult to explain the differences in the results obtained at the various mines, for these factors may vary in different parts of the same mine. In general they may be summarized as follows: (1) Physical structure of the coal and roof, (2) extent of undercutting and snubbing, (3) methods of use, (4) order of firing shots, and (5) width of workings.

PHYSICAL STRUCTURE OF THE COAL AND ROOF.

Conditions favorable and unfavorable to shooting down coal are usually indicated in the production of coal per unit of explosive used. The thickness of the bed, its cleat, friability, the nature of the roof, and impurities, such as shale or "sulphur" bands and irregularities, all affect blasting. Other conditions being equal, the thicker the coal the greater is the production per unit of explosive. The No. 6 bed has certain characteristics which tend to affect the ease of mining, such as the absence of definite cleat, and the variation presented in the three distinct benches—the brittle top coal, the somewhat stronger middle bench, the "blue band" parting, and the firm and hard bottom coal. The average production per unit of explosive in coals No. 5 and 6 is not in proportion to the thickness of the beds. In mining the No. 6 coal the top layer of coal is left for roof and the parting is not so free as the more pronounced roof separation of the No. 5 coal in Saline County. This is especially true where the roof is a light-colored shale, for then the parting is very distinct and the coal breaks away freely. The cleat in No. 5 coal in Saline County is probably more pronounced than in the No. 6 coal anywhere in the State. Consequently where No. 5 coal has its maximum thickness the production per unit of explosive is slightly higher than the average for No. 6 coal.

As to friability, these coals are regarded as being somewhat stronger and firmer than the average bituminous coals and they withstand shipment well. Tests to determine breakage due to handling tend to show that Illinois coals shot by permissible explosives are not affected materially by handling as compared with the same coals shot by black blasting powder. Especially in the egg and nut sizes these coals are firm and hard and suffer little loss from breakage in ordinary handling.

In certain mines in the No. 6 bed, where limestone closely overlies the coal with 2 to 8 feet of shale intervening, the top coal is not left up, but is often unusually hard and contains many bands of "rock" and "sulphur." Such bands affect both the cost of mining and the sizes produced, because greater explosive force is required to break the coal and in the removal of impurities the coal undergoes further breakage. Often "sulphur" bands or "rolls" are encountered in drilling and the miner is compelled to shoot a short hole with possibly unsatisfactory results and at increased cost.

Plates VII and VIII show the No. 6 coal after being shot down with permissible explosives in typical mines in Franklin County.

UNDERCUTTING AND SNUBBING.

Table 1 (p. 22) shows that the average depth of undercutting by chain machines in the 18 mines listed is 6 feet, with a maximum of 7 feet and a minimum of 5 feet. The average depth of undercutting by puncher machines is 4.75 feet. As the amount of explosive used in practice is not proportional to the depth of the drill hole or the depth of undercutting, it would appear that the production of coal per unit of explosive used should be slightly increased for the deeper undercutting. Undercutting 6 to 7 feet, with adequate "snubbing," has in most mines been found satisfactory. The undercutting is always done in the coal.

The saving of explosive by proper undercutting is too often overlooked, although the advantage gained by giving the explosive the best possible chance to work can clearly be measured by the results obtained. If the coal is not "snubbed," it may rest rather firmly on the bottom, so that extra work is required to release it; and if undercutting is incomplete and small solid blocks, coal sprags, or cuttings are not removed from underneath, the shot can not properly do its work and a part of the advantage of undercutting is lost. The explosive force follows the lines of least resistance and can do only a certain amount of work.

Some machine men do not finish the undercutting square with the rib when using the short-wall machine The machine is pointed into the rib at the back of the cut and then withdrawn at an angle. This prevents placing the rib hole to advantage, and as a result the left rib will break in a "zigzag" fashion. The miner in endeavoring to maintain a straight rib will angle the hole in toward the solid coal; extra explosive is required and the results are less satisfactory.

Data from two mines, shown in Table 3, give a proportionately larger production per unit of explosive with the 7-foot machine as compared with the 6-foot machine. In some instances less explosive was used after a 7-foot machine than after a 6-foot machine in rooms on adjoining entries. The miners noted no difference in the work of loading out the coal. It is thought that the 7-foot cut is the maximum for good results in this field.

The method of snubbing back half the distance of the undercutting is a good one. At some mines hand snubbing is rather difficult but for the most part the coal is suitable for snubbing and is easily broken down in slabs. Often the bottom layers of coal immediately above the undercut will break down from the weight, thus assisting snubbing. Snubbing benefits both the miner and the operator. It is to the miner's advantage because it saves explosive and makes the work of obtaining the coal easier. Usually the face breaks at an angle, with the top projecting out 2 feet farther than the bottom. When snubbing is properly done, the coal when shot falls forward and rolls over, thus giving the miner the same advantage as in loading after puncher machines. As there is usually a differential in the rates for loading after chain machines and after puncher machines, and as coal mined with chain machines and snubbed presents practically the same conditions as coal undercut with puncher machines, the miner can consider that he is being paid for snubbing at the rate of the number of tons of coal loosened per round of holes times the difference between cost of loading per ton after puncher and after chain machines. In Franklin County this difference amounts to 6 cents per ton; the amount of coal shot down in a room 24 feet wide, 7½ feet high, and a 7-foot undercut averages about 50 tons; then 50 times $0.06 equals $3, which represents the value of snubbing. Snubbing also gives better sizes of coal, which is an advantage to all parties concerned. Frequently, however, the miner neglects to do enough snubbing. At some mines the shot firers refuse to shoot shots when the snubbing is inadequate; at other mines face bosses are employed who in addition to other duties supervise snubbing.

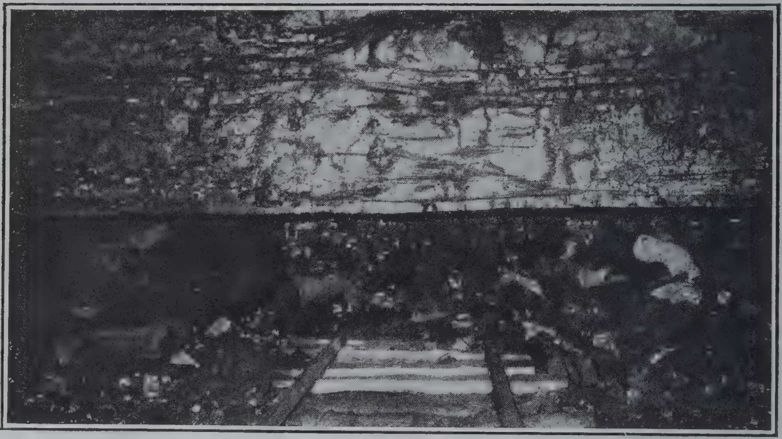
ADVANTAGE OF FIRING "SNUBBING SHOTS."

In a number of mines where the coal mined averages 8½ to 9 feet, and up to 10 feet, thick "snubbing shots" are fired. Inasmuch as the limit charge of permissible explosive is often exceeded under average conditions, snubbing shots are necessary in the thicker coal and could be employed to good advantage throughout the field. In the mines in Franklin County the average thickness of coal worked is about 8 feet. The top coal, in which holes are drilled under present methods, is a brittle coal. Sufficient explosive must be inserted to break down 7 to 8 feet of coal. The bottom bench below the "blue band" ranges from 1¼ to 3 feet thick and is by far the hardest part of the seam; in some sections the "blue band" is 2 to 3 inches thick and in places very hard to break. Thus it can be seen that under present methods the firing of three shots to break this entire thickness of coal, with the hardest part of the seam the farthest from the explosive and with the explosive embedded in the more

A. FRESHLY SHOT FACE OF NO. 6 COAL IN FRANKLIN COUNTY MINE USING PERMISSIBLE EXPLOSIVES.

B. RESULT OF SHOT WITH PERMISSIBLE EXPLOSIVE IN FRANKLIN COUNTY MINE, SHOWING COAL ROOF.

C. LUMPS OF COAL PRODUCED WITH PERMISSIBLE EXPLOSIVES, NO. 6 BED, FRANKLIN COUNTY.



A. FACE OF ROOM IN NO. 6 COAL, FRANKLIN COUNTY MINE, AFTER "SNUBBING SHOTS" HAVE BEEN FIRED. COAL BROKEN AWAY AT THE "BLUE BAND."

B. ROOF OF NO. 5 BED AFFECTED BY FIRE. A FREQUENT CONDITION IN MINES IN WHICH BLACK BLASTING POWDER IS USED.

brittle top coal, requires excessive charges and such charges must tend to increase the proportion of screenings.

Plate VIII, *A*, shows the results of snubbing shots in coal 9 feet thick. The coal underneath the "blue band" has been broken down, giving excellent lump. After this has been loaded out, or even partly loaded out, the remaining part can be shot down with good results. A special tool, an iron rod three-fourths of an inch in diameter and about 6 feet long, with a handle on one end and a prong or hook on the other, can be used efficiently for pulling out the coal produced by the snubbing shots. This total is known as a snubbing or coal hook.

MINING "ON THE BENCH."

In order to furnish for this report some data on the practicability of mining "on the bench" in the No. 6 bed, a test was conducted at the West mine, at West Frankfort, during the latter part of March, 1916, by Robert Forsyth, superintendent of the West Frankfort Coal Co., who first proposed trying out such a method as early as 1909, at the time explosions were so frequent in this field. The method, although not new for Illinois, had never been tried previously in Franklin County. The accompanying sketches in figure 16 show the features of this method.

This test was made in rooms 3 and 4, off the third southeast stub entry. In order to establish the "bench," the mining machine was unloaded onto a specially erected platform, so as to raise the cutter bar to the desired height. The first cutting was made across the face of the room immediately above the "blue band" in the soft coal, 5 to 6 inches thick, occurring just a few inches above the "blue band," as in A, figure 16. The coal was then snubbed by hand 1 foot high and 2½ feet deep, as is the regular custom, and shot down with three holes with two and one-fourth sticks of explosive in the center hole and two sticks in each rib hole. In regular shooting with three holes, when the mining is on the bottom, four to five sticks of explosive per hole are used. This fall was then loaded out and another cutting put in, as shown at B, figure 16. This time, however, the machine was unloaded on the bench, and the cutting was done in the usual way. The height of coal above the bench was 5 feet 5 inches. Another round of shots was fired, and as the bench had already been established, this coal was loaded from the bench directly into the car, the bench being 2 feet 4 inches high, thus giving the miner the advantage of much easier loading. After this coal was loaded out, a third cutting was made and three holes again drilled and charged, as shown at C, figure 16.

The plan then required shooting up one cut of bottom in order that the face of the coal could be kept at a uniform distance from the track, so three holes were accordingly drilled in the bottom coal, and one stick of explosive was placed in the center hole and three-fourths of a stick in each rib hole. This shot the bottom very successfully, giving practically all lump coal, as the shots merely loosened the coal in large lumps. The bottom holes were placed as shown in C and in the front view, sloping downward into the bottom clay from a starting point about 6 inches from the top of the bench. The center shot in the bottom coal in room 4 was drilled downward from the top of the bench, about 4 feet back from the edge, at an angle into the clay. Tabulated results of the shots follow:

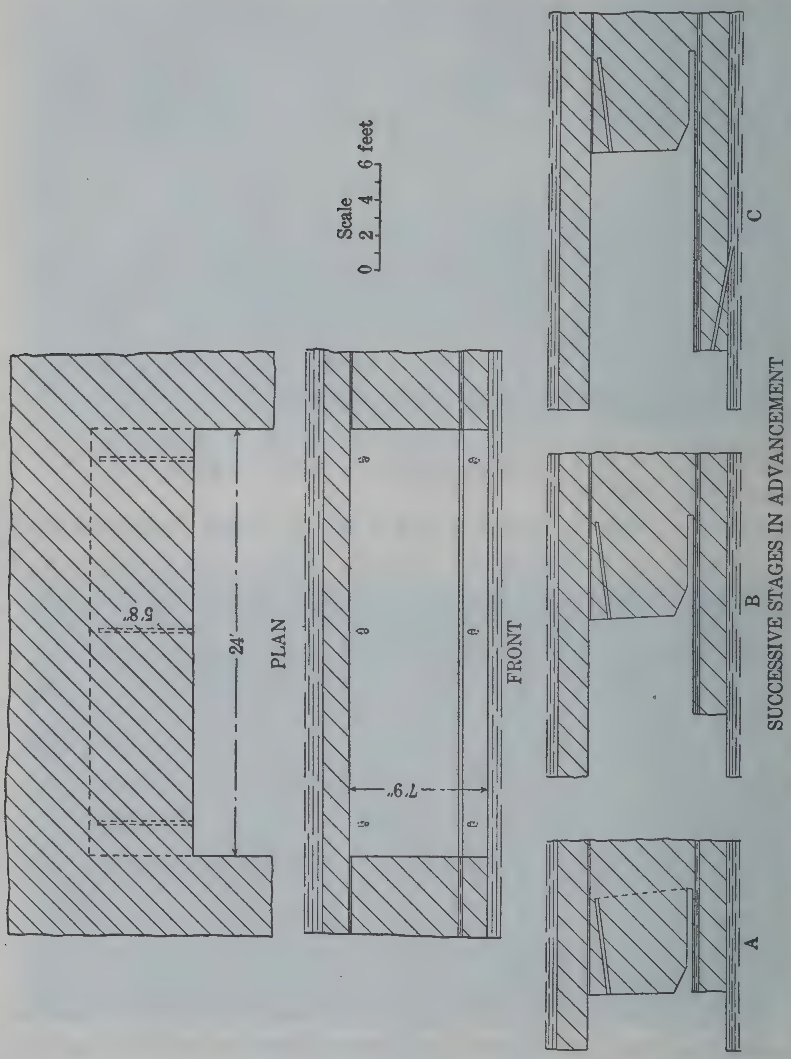


FIGURE 16.—Mining on the bench, showing successive stages. From tests in a Franklin County mine to determine results obtained from using permissible explosives.

Results of shots with a permissible explosive test of mining "on the bench" in a Franklin County mine.

Location.	Width of room.	Total thickness of coal.	Thickness of coal shot.	Depth of undercutting.	Snubbing.		Position of hole.	Depth of hole.	Distance of hole from roof.	Distance of hole from rib.	Number of sticks of explosive used for each shot.	Total sticks of explosive used.	Total pounds of explosive used.	Number of tons of coal produced.[a]
					Height.	Depth.								
	Ft.	*Ft. in.*	*Ft. in.*	*Ft.*	*Ft.*	*Ft.*		*Ft. in.*	*Ft. in.*	*Ft. in.*				
Room 3, 3 southeast stub entry:														
Top shots[b]	24	7 9	5 5	5½	1	2½	Left	4 8	0 10	1 0	2	6¼		30
							Center	4 8	0 10		2¼			
							Right	4 8	0 10	1 0	2			
Bottom shots			2 4				Left	4 0		1 0	¾	2½		11
							Center	4 0			1			
							Right	4 0		1 0	¾			
Total												8¾	4.5	41
Tons per 25-pound box of explosive														225
Room 4, 3 southeast stub entry:														
Top shots	26	8 1	5 8	5½	1	2½	Left	4 9	1 0	1 3	2	6¼		32¾
							Center	4 9	1 0		2¼			
							Right	4 9	1 0	1 4	2			
Bottom shots			2 5				Left	5 0		1 2	1¼	3¾		13
							Center	3 6			1¼			
							Right	4 10		1 2	1¼			
Total												10	5.16	45¾
Average tons per 25-pound box of explosive														222

[a] Average tons produced per 25-pound box of explosive, 223.5; average for these rooms under the present method is about 175 tons.
[b] Top holes drilled within 3 inches of roof.

It is felt that as so large a part of the future production of coal in Illinois will be from coal No. 6, any innovation in mining methods that will encourage the use of permissible explosives and lead to production of less fine coal and possibly increase the miner's earnings, besides giving other advantages, should be carefully considered.

The advantages of the system described might be enumerated as follows: Possibly larger sizes of coal can be produced, and with less explosive. Loading off the bench makes work easier for the miner, as the coal on the bench can be shoveled directly into the car and need not be raised the full height of the car, and the "blue band" can be removed more easily. A row of props can be carried on the bench close to the face, thus insuring greater safety and fewer accidents from roof falls; also a permanent row of props can be kept up to the bench, and the miner can stand on the bench and set these props to advantage. The miner can examine the roof more thoroughly; the undercutting can be done more quickly, as the coal is softer at this point; and bits will require only about one-third as much sharpening as when cutting in the hard bottom coal. Drilling will be easier for the miner standing on solid coal than, as at present, standing on a box while drilling coal 7½ to 8 feet high. The use of smaller charges of explosive will be easier on the roof and break it less, an extremely important matter in Franklin County where the coal roof is left up; the limit charge of 1½ pounds of explosive will not be exceeded, which overcomes the objectionable feature of placing heavy charges of explosive in top coal, as is necessary in breaking down 7½ to 8 feet of coal with a hard bottom bench. No changes need be made in the types of mining machines now in use except that possibly wheels of larger diameter, 18 to 22 inches, might be employed for the machine truck, so that the mining machine can be unloaded directly onto the bench when the bench is once established. At times only the middle bottom shot need be fired with this method, and then the bench is not only in front of the car but along the sides as well, as space can be made for extending the track.

The principal disadvantages of this method are that, from the miner's standpoint, it will require the drilling of three holes more than by present methods and possibly better workmanship in taking up the bottom coal in some places. Also it will make a change in conditions. However, its advantages are believed to overbalance greatly any disadvantages. The use of electric drills would obviate such extra work, and these drills should be used, provided that suitable changes in the wage scale were made.

METHODS OF USING EXPLOSIVE.

It is generally conceded that it requires an experienced miner to get the best results from permissible explosives, as from black blasting powder; it is also the belief that a miner has advanced in his vocation when he can also use permissible explosives successfully. The miner who has become accustomed when using black blasting powder to angle the holes into the ribs and drill them slightly on the solid finds that permissible explosive will not give the best results under such conditions. When permissible explosives are used, the hole should be practically parallel with the rib and have sufficient clearance from the rib and from the back of the undercutting. The inclination of the hole may vary slightly.

The excessive use of explosive increases both the cost per ton of coal and the amount of screenings produced. The tendency to use too much explosive is one of the most detrimental factors to the success of permissible explosives in any mine. The miner's inherent dislike to spend time picking down coal after a shot tends to result in shots being overcharged except by miners who consider the saving from using the proper amount and the danger to life and property from an overcharged shot.

The sizes of the sticks of explosives as used in Illinois mines are 1¾ by 6 or 1¾ by 7 inches. The limit charge, 1½ pounds, would restrict the amount used to three sticks or less per shot, giving a charge 18 to 21 inches long, which would occupy about one-third of the drill hole. As noted in Table 2, the number of sticks in a 25-pound box of explosive varies from 40 to 53, depending upon the size of the cartridge and the density of the explosive. In a 25-pound box containing 40 sticks of explosive, the average weight per stick is 10 ounces; in a box containing 50 sticks, the average weight per stick is 8 ounces; therefore, it follows that two and one-half sticks of the former would do the same work as three sticks of the latter, assuming that the sticks of explosives are of equal strength. For this reason it is often to the miner's advantage to cut a stick into halves or even into quarters. The accurate judging of the amount of permissible explosive to use is highly important with respect to the sizes of coal produced.

Closely associated with the improper use of explosives is the dissatisfaction that may result from misfires, or failure of shots, which are due to a number of causes almost wholly within the province of the miner to prevent. Preventive measures include care in the storage and handling of explosive, fuse, and detonators, and the careful preparation of shots, as previously mentioned. Misfires are costly, resulting in smaller output, waste of explosive and loss of time and increase of danger in drilling and charging a new hole.

It has been suggested that it would be advisable for operators to provide for the supervision of snubbing and of the arrangement and charging of shots. Often the shot firers have assisted in this work, giving instruction where necessary, and have thus aided in bringing about better results, to the miners by improving methods of work and to the operator by increasing the proportion of the larger sizes of coal, and in improving safety. The shot firer by virtue of his work is in a position to command the confidence of the men, to detect improper practices, and to assist in establishing safer practices. The careful selection of shot firers has had much to do with the successful use of permissible explosives.

ORDER OF FIRING SHOTS.

The system of lighting three shots at a time in a room, when firing with fuse and detonator, is somewhat general. This system tends to increase the proportion of screenings and also increases the amount of explosive necessary and consequently the explosives cost to the miner, for often the ''buster'' or center shot, which is given a shorter fuse and is fired first, will break the coal nearly to the adjoining rib shot, leaving only a relatively small amount of coal to be broken down by the previously charged rib shots. The rib holes are charged on the assumption that a certain amount of coal will be left standing, whereas if the miner could see the amount to be shot, he could gage the charge for the rib shots more correctly, and thus save explosive. Therefore there is an advantage in firing the ''buster'' shot before the rib holes are charged; in other words, firing the ''buster'' one night and the rib shots the following night, and this should be done at every opportunity. The coal from the ''buster'' shot need not all be loaded out before the rib shots are fired.

As each two miners have two working rooms, also a crosscut through the pillar every 60 feet, such practice can be frequently followed. Usually, however, in order to avoid delay in undercutting, the face in one place is squared up and made ready for the machine men before any coal from shots in the adjoining room is loaded out, and at times it could not be followed.

At one mine the rule is to charge and fire not more than two shots in a room on any one night. This has the advantage of supplying ample coal for a day or more and the charge required for the remaining rib shot the following night can be accurately judged. In the various mines a depth of undercutting of 6 feet on a face about 24 feet wide yields approximately 40 tons; a 7-foot cut yields 50 tons. Each place is cut and shot on an average not oftener than twice each week, which with two men and two rooms provides 160 to 200 tons to load, not including the coal from the intervening crosscuts. The average daily tonnage [a] per miner in these fields indicates that such a system can be followed, and often the firing of a single shot per night would be practicable. Table 3 gives data on the average production of coal per shot.

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[a] Data by Andros show a daily output of 7.6 tons per loader for the sixth mining district. See Andros, S. O., Coal mining in Illinois: Bull. 13, Illinois Coal-Mining Investigations, Cooperative Agreement, 1915, p. 148.

Data from a typical mine for the year 1915 follow:

Number of tons produced per day by each loader in an Illinois mine during 1915.

	Tons.
January	11.48
February	11.20
March	11.99
April	12.19
May	11.50
June	11.16
July	11.63
August	([a])
September	11.55
October	11.93
November	10.75
December	10.90
Average	11.48

WIDTH OF WORKINGS.

The working dimensions are fairly uniform in the mines listed, the rooms average 24 to 26 feet wide; the width of room necks varies. Including room necks and crosscuts, the usual ratio of wide places to narrow work is about three to one. In one mine coal was at one time being produced from 220 rooms and 68 entries; in another mine, from 186 rooms and 50 entries, not including entry and room crosscuts; in another, 170 rooms and 30 entries. In a number of the Franklin County mines where the rooms are driven their full length, the last crosscut is made 18 feet wide at the face, connecting all rooms and making a continuous face, which gives a larger proportion of wide work, and consequently helps to increase the percentage of lump coal.

In one new mine in Franklin County, data on all development work 12 feet wide shows an output of approximately 100 tons of coal per 25-pound box of explosive, the percentage of 2-inch screenings being slightly over 50 per cent. It is believed that when the mine is being operated at full capacity, the proportion of screenings will be decreased 7 to 10 per cent with a corresponding increase in the larger sizes. Data from one mine fully developed, in which 257 rooms averaging 24 feet wide and 70 entries averaging 12 feet wide, were being worked, show that 94 per cent of the coal is from rooms and room crosscuts, and 6 per cent from entry and entry crosscuts.

Data given in previous pages show that the cost of blasting per ton of coal in entries is practically double that of wide rooms. Table 4 shows that the average production per 25-pound box of explosive is 209 tons in rooms and 104 tons in entries, and that in the various typical mines the production per unit of explosive increases with the width of workings.

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[a] No data available.

Coal produced from pillars or from areas affected by squeezes yields a high percentage of screenings, but in the mines under discussion the amount of such coal is practically negligible as few pillars are drawn and little coal is obtained from squeezed areas. The amount of top coal recovered is also very limited.

The relative proportions of different sizes of coal, which are affected to more or less extent by these various factors, are also influenced by breakage resulting from the handling underground, and in the various methods of preparation. Holbrook's report [a] on the preparation of coal at Illinois mines contains interesting data on this subject.

In the foregoing, recognition of the many obstacles that the miner and management meet and the difficulty in overcoming them have not been lost sight of, but the fact remains that some of these are inherent to mining. Each division of underground work bears a relation to every other division, and all should move in harmony toward the objectives—greater safety, less explosive per ton of coal produced, and larger sizes of coal.

ADVANTAGES OF PERMISSIBLE EXPLOSIVES.

Rutledge and Hall [b] mention the advantages of permissible explosives over black blasting powder, as found in practice throughout the various mining districts as—lessened risk of fire, making fire runners unnecessary, less damage to roof, cleaner ribs, fewer blown-out shots, less scattering of coal, fewer air blasts (shocks to the mine air), and windy shots, permissible explosives better adapted for use in wet holes, absence of smoke, pleasanter and safer mining.

These advantages have been clearly shown in Illinois mining practice and are discussed relative to the following: Fires and explosions, blown-out and windy shots; effects on roof, accidents, effect on general mine efficiency.

MINE FIRES AND EXPLOSIONS.

The occurrence of fires and explosions from the use of black blasting powder has been pointed out in preceding pages. No data have been kept of costs of the various fires, but even should no widespread disaster occur through them, yet the frequent occurrence even of small fires is a source of great anxiety and expense. When a fire is discovered in its early stages it is easily smothered, but often it may smolder in newly shot coal and the fire runner may pass by without detecting it. If the fire is under headway it is often necessary to seal off a considerable area of the mine, which results in loss of wages and output, and in addition to this entails the cost of sealing, opening, and cleaning up several hundred feet of entry, and the dangers attending this work. Especially in mines having a high volatile coal, bad roof, and generating explosive gases, the problems created are expensive and serious. The subsequent bad roof conditions are an additional source of expense and danger. Plate VIII, *B*, shows the after effects on the roof of a fire from a black powder shot in a mine working No. 5 coal. Practically all of the mines in which permissible explosives are now used and which formerly used black blasting powder have had trouble and expense from fires. At one mine 20 fires occurred, each of which cost $100 to $500 to combat; at another mine 12 to 15 fires occurred, which stopped mining one to three days and cost $50 to $300 each to fight. These figures do not include losses in wages and output. At another mine several large fires have occurred. On one occasion both shafts had to be sealed for a period of nearly seven weeks. Within two months another fire started which required the erecting of five stoppings and the sealing off of 80 working places, with all miners' tools and one mining machine. The cost of sealing off this fire was $1,100, to which must be added the subsequent and indirect costs. A tabulation of the costs of fires in the various mines would form an item possibly aggregating, in proportion to the value of the property involved, the cost of fires in some of our larger cities.

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[a] Holbrook, E. A., The dry preparation of bituminous coal at Illinois mines: Bull. 88, Eng. Exp. Station, University of Illinois, 1915, p. 133.

[b] Rutledge, J. J., and Hall, Clarence, The use of permissible explosives: Bull. 10, Bureau of Mines, 1912, pp. 20–25.

The necessity of providing fire runners in the various sections where black blasting powder was used created a daily expense item of considerable amount.

In so far as the elimination of fires and explosions is concerned, it can be stated that the use of permissible explosives has effectively met the situation in the districts where used.

It is true that small fires have sometimes resulted from the use of permissible explosives, but these have been caused chiefly by the improper use of such explosives, from a number of causes, as follows: (1) Using more than the limit charge of 1½ pounds of explosive (any explosive when used in excess becomes more dangerous); (2) using insufficient stemming or no stemming, especially in the presence of gas feeders; (3) the use of damp explosives or weak detonators, either of which may cause the explosive to burn instead of detonate or may cause a detonation of a low order which would destroy the main feature that makes an explosive permissible; (4) the use of explosive which has changed in composition through age or in which the nitroglycerin has segregated through long or improper storage so as practically to change its composition; (5) the use of two kinds of explosive in one drill hole; and (6) the use of damaged fuse, the "side spitting" of which may ignite a gas feeder or else ignite the explosive, causing an initial burning.

In nearly every instance in which fires from explosive have been reported in Illinois mines using permissible explosives, evidence was at hand to point to one of the above causes. At one mine a small fire followed a "tight" shot on the rib. The miner had kept his box of detonators buried under several inches of dirt and the detonators had become moist. The charge was undoubtedly incompletely detonated and burned in the drill hole. At another mine the use of old explosive caused a fire; at another three fires from one of the permissible explosives first placed on the market occurred during the first few months that permissible explosive was used, but the cause is not known. In two other instances, fires were reported, due in one instance, it was thought, to the fuse "side spitting" and in the other to the explosive burning. Only few fires were reported during the past year in the Illinois mines using permissible explosives, although approximately 800,000 shots were fired. No explosions have occurred in several millions of shots.

The importance of care in the use and storage of explosives applies directly to the prevention of fires. In one mine in which during 1916 two fires occurred from shots of permissible explosive an investigation was made and it was found that in the storage of explosives in the magazine a fresh shipment had been stored on top of much older explosives, resulting in some of the explosives being much too old for safety or efficiency when finally used. When a new consignment of explosives is received, it should be stored in the magazine in such a way that the oldest explosives can be issued first. An instance is reported of a carload of explosive being kept on hand for over a year and only four boxes were discarded, the remainder being used after this time; this, however, is an exception and it is generally believed that explosive over six months in age should not be used. If a carload can not be used in this time, the explosive should be purchased in smaller quantities.

Some of the causes of fires as given above refer to the use of old or deteriorated explosives—explosives that would fail to pass the tests for permissibility. In others it is assumed that the explosive used is in all respects similar to the sample that passed the required tests at the Pittsburgh testing station of the Bureau of Mines—that is, it is a standardized permissible explosive. During the winter of 1916-17, at one mine there was trouble from a certain explosive that burned in the drill hole. A number of small fires resulted and one fire which got beyond control had to be sealed. As the cause was not apparent and the fires were confined to a particular mine, the manufacturer was asked to investigate the matter. Later the trouble was overcome. This experience again demonstrates the readiness with which the coal face in the mines in southern Illinois ignites and the desirability of using short-flame explosives only in these mines; also, that in combating the fire hazard, the cooperation of all parties concerned is necessary.

Two field samples of the explosives sent from Illinois mines to the Pittsburgh testing station at various times exceeded the allowable tolerance, and the particular lots of explosives represented by such samples were therefore declared nonpermissible.

BLOWN-OUT AND WINDY SHOTS.

The characteristic action of permissible explosives helps to prevent blown-out and windy shots such as occur with black blasting powder. The explosive expends its energy on the coal and tends to crater or enlarge the hole rather than to blow out of the hole. Overcharges will not give windy shots with accompanying blowing out of props and brattices and derangement of ventilation, as would a corresponding overcharge of black blasting powder. The feeling of relative safety among shot firers in mines using permissible explosives sometimes tends toward a disregard of necessary precautions. Care should be exercised, and the explosive should always be in good condition, properly tamped, and fired with full strength detonators.

EFFECTS ON ROOF.

In comparing black blasting powder and permissible explosives as to their relative effects on the stratum that forms the immediate roof, some difference of opinion may exist. All mining men agree that any explosive may injure the roof. In Franklin County from 10 to 40 inches, usually about 24 inches, of top coal is left for roof to hold the shale which falls when exposed. The poor roof conditions typical of the No. 6 coal after the overlying shale becomes broken are illustrated in Plate I (p. 6). The effect of the explosive on the roof is therefore of considerable importance, as often bad roof conditions are a serious hindrance to mining.

Black blasting powder, like other explosives, exerts force in every direction, but as it acts slowly its gases can work upward through cracks and crevices. As the natural roof is harder than the coal, this effect is not readily observed. In some of the Franklin County mines soft friable shale containing many parting or bedding planes and crevices overlies the coal. The slowly generated gases from black blasting powder work up into these planes or if, in the case of "frozen" or sticking coal it is necessary to place the shot close to the roof, the powder gases "burn" through these crevices. When this occurs, in many cases the roof may apparently be in good condition after the shot and may stand for two or three months, and then break down from the combined action of air and moisture in the cracks enlarged and weakened by the shot of black powder.

The gases generated from explosives of the permissible types do not "work ahead" like black blasting powder, also do not work up into and weaken the roof. The gases are generated so suddenly and the energy is so quickly dissipated that the coal breaks much more quickly and the liberated gases can not work into these crevices, make new crevices, or enlarge the old ones. This feature of these explosives assists in making them "permissible."

In the No. 6 seam there are a number of partings in the friable top coal, and often when black blasting powder was used the gases did not follow the regular parting planes but worked far up into the top coal. This condition can be traced in a number of mines in the Franklin County field, where black blasting powder was formerly in use; in fact, the places along the entries can be noted where the change from black blasting powder to permissible explosives was made. The flame of black blasting powder would spread out from the end of the drill hole and follow along the different partings, especially when the hole sloped upward too much. The characteristic action of permissible explosives is noted when the hole projects upward into the plane beyond that intended; in this event "holing out" results—which, however, is of limited extent. Miners often drill upward, or into the ribs, more than is desirable for the purpose of gaining a greater production per unit of explosive, and this tendency has to be guarded against on account of the greater amount of timber necessary. The character of the roof of the No. 6 coal and a method of timbering an entry are shown in Plate I (p. 6), which illustrates a problem met in all these mines.

Experience in Franklin County and other mining districts shows that permissible explosives are much easier on the roof than black blasting powder. In a Pennsylvania mine, in a powder test, a series of about 100 shots was fired with black blasting powder, and then a series with a permissible explosive. There was a "draw slate" about 9 inches thick above the coal, which was mined with the coal, and the holes were drilled so that the point of the hole came close to the parting between the coal and this "slate." The conditions as to the placing of holes were observed for each shot, and all holes were charged under the supervision of a committee of miners and operators. It was found that in almost all cases black blasting powder caused the "slate" to fall with the coal, or shortly thereafter, whereas when the coal was shot with the permissible explosive the "slate" invariably had to be shot separately. This extra blasting may have increased the cost slightly in this particular mine, but it shows that the use of permissible explosives undoubtedly tends to be easier on the roof, and thus lessen the danger of roof falls.

In the majority of mines where permissible explosives are used it is the opinion that they are much easier on the roof. In one mine where poor roof is encountered, permissible explosives are giving much better results than were previously obtained from black blasting powder. In another mine the only instances in which results were unsatisfactory were in some entries where the dip of the bed changed and the entrymen drilled up into the roof before they were aware of the situation, resulting in a poor roof for some distance. At another mine, where the parting planes are not always pronounced, holes are often drilled across these planes, but the roof is not seriously broken; a small cavity may result, but not enough to require extra timbering. At still another mine, where permissible explosives are used, it was thought at first that the explosive was damaging the roof, but further observation showed that this was due to local conditions; and further on, where conditions became normal, these effects disappeared. Exceptionally good roof conditions were noted throughout one mine where permissible explosives have been used exclusively. In this mine the props were recovered from practically all of the rooms of one pair of panels that had been driven up to the boundary, and the roof held well without a break for some time. In some places the roof of a whole room, with an area of 24 by 250 feet, held for weeks after all the timbering had been removed. This is rather unusual for the roof of No. 6 coal. The superintendent at this mine estimates that the use of permissible explosives has saved his company many thousands of dollars in timbering.

In the No. 5 seam no top coal is left, and the coal is shot free from the roof, as has been previously stated. In one particular mine the roof is of light-colored shale, which gives a free parting and consequently a higher production of coal per unit of explosive. At three other mines no damage to the roof from permissible explosives has been noted. In only one mine of the entire district was it believed that permissible explosives had a more damaging effect upon the roof than black blasting powder, and it was thought that the miners could overcome this by properly placing and loading the holes.

FEWER ACCIDENTS FROM PERMISSIBLE EXPLOSIVES.

Permissible explosives are not easily ignited by a spark from a lamp, a frictional spark, or a flame from burning gas, and are not exploded by an electric current unless detonators are present, and hence there is less possibility of accident than when black blasting powder is used. Illinois mining history has recorded numerous instances of fatal and nonfatal accidents from the use, misuse, and transportation of black blasting powder, but in spite of the fact that only a small percentage of the miners were at all familiar with permissible explosives at the time of their introduction, the accident record is singularly free from accidents due to the use or handling of permissible explosives. Franklin County records show only two fatal accidents charged to permissible explosives, one of which is said to have resulted from a miner prying with the point of his lamp hook into a detonator that had misfired. His act is supposed to have exploded the fulminate in the detonator, which in turn exploded some near-by detonators and a 25-pound case of a permissible explosive.

Defective squibs, powder ignited by burning gas, by a spark from a lamp, spark from smoking tobacco, by a spark in drilling out a missed shot, by a spark from a pick in opening a powder keg, or by an electric current or arc, all took their toll in lives. With permissible explosives practically all these dangers are removed, provided reasonable care is exercised in handling the sensitive detonator.

It has been frequently noted that the heat of an explosion of gas or dust readily sets off black blasting powder, which may increase the force of an explosion and at times renews one that has practically died out. During the fiscal year ended June 30, 1915, two explosions in Illinois mines were reported to have been started by the ignition of bodies of gas, black blasting powder being used in one of these mines and permissible explosives in the other. These accidents afford a comparison of the effects on the different explosives when exposed to the heat and violence of an explosion. In one of them numerous kegs of black blasting powder were exploded by the heat. These had been delivered the night previous and were full, unopened kegs, as shown by the unopened bungs, ignition having been caused by external heat. In the other, several boxes of permissible explosives had been thrown against the ribs and broken open and the contents scattered along the entry without the explosive being ignited or detonated. Evidences of extreme heat after both explosions were the remains of rolls of charred fuse, burnt clothing, paper, and coked dust. Furthermore, should any permissible explosive be set off under such conditions, on account of the factor of safety which its relatively short flame provides, there is much less likelihood of its contributing to the loss of life and property than of such loss being caused by black blasting powder. Detonators, however, are very sensitive to blows and they should be stored at a safe distance from the explosive. The fewer kept in the mine by the miner the better.

In the mines using permissible explosives, shots that have misfired are occasionally drilled out. No accidents have as yet been reported, but such practice is extremely dangerous. The best practice is to tamp the "missed" hole to its mouth and to drill and load a new hole at least a foot from the old one. In one instance noted the miner drilled a new hole because of a misfire, and after shooting the new hole found that the explosive from the first hole had not been detonated.

Additional evidence of the dangers of using black blasting powder was furnished by an accident in August, 1915, in a mine in southern

Illinois in which the miners tamped their own shots, and firing was done by shot firers. One miner, contrary to rules, approached the drill hole with his carbide light on his head, and as he pushed the cartridge of black blasting powder into the hole a quantity of gas was forced out and ignited by flame from his carbide lamp. As the miner ran down the entry the powder ignited and, exploding in the drill hole, gave rise to a "windy" shot which might have resulted disastrously.

EFFECT ON GENERAL MINE EFFICIENCY.

Under general mine efficiency may be included other advantages tending to make the use of permissible explosives satisfactory in these fields.

Fire runners are now unnecessary in these mines, whereas they were previously required when black blasting powder was used.

Permissible explosives withstand moisture better than black blasting powder and the explosives of the nitroglycerin class, especially, can be used in wet holes if the detonator is properly arranged.

There is less work in making up the charge with a permissible explosive and less danger. Cartridges are uniform in size and weight and the charge can be accurately gaged. This is important in undercut coal where equal charges of explosive are used daily.

A given quantity of a permissible explosive can do more work than a similar quantity of black blasting powder; hence fewer holes need be drilled and charged to shoot down the same amount of coal.

The quantities of smoke and noxious gases given off by permissible explosives are relatively small as compared with black blasting powder, and this, with the smaller quantity of explosive used per shot, is an immense advantage as regards the effect on the miner's health. No permissible explosive produces more than 158 liters (5.5 cubic feet) of poisonous gases per 1½ pounds of explosive and most of them produce less than 120 liters (4.1 cubic feet). This excellent feature is overlooked to a great extent because all of the men except the shot firers are out of the mine at the time of firing, but is of additional advantage to the shot firers, as they can travel with greater safety. Shot firers are protected in their work and find the explosion hazard greatly decreased.

SUMMARY AND CONCLUSIONS.

The advantages of permissible explosives emphasize the important bearing that these explosives have on the prevention of accidents and property loss. Their introduction into Illinois mines was difficult, but, after a thorough trial, they have been accepted as the explosives most suitable for conditions in the respective mines in which they are now used. In making a change from one mine to another or from one grade of powder to another the miner must necessarily familiarize himself with the new conditions in order to do efficient work. This applies directly to a change from black blasting powder to permissible explosives. With a better knowledge of the nature and merits of the permissible explosives, their users give many testimonials as to the advantage gained, a condition most pleasing to the advocates of greater safety. The consensus of opinion among mining men in these districts is that where the coal is undercut and snubbed, permissible explosives can be successfully used, with little, if any, increase in the production of slack.

The cost of explosive per ton of coal produced in these mines has been lowered, owing to the fact that less explosive is required to perform the same work than when black blasting powder was used, the sizes of coal compare favorably, and miners accustomed to the use of permissible explosives get as good results as they did with black blasting powder.

Results are more favorable than was anticipated by the early users of permissible explosives. It was thought there would be a large difference in the sizes of coal produced and in the cost of explosives per ton of coal, as compared with black powder. In mines where the value of the coal produced has been affected by an increase of 2 to 5 per cent in the production of screenings, it is felt that this is compensated by the increased safety through the elimination of fires and explosions, saving in wages of fire runners, fewer accidents in handling explosives, and the feeling of security which the use of permissible explosives gives; these considerations also offset the loss of the profit the operator previously gained by handling black blasting powder. In other mines no material loss has been sustained, whereas in certain mines it is believed that the less injurious effect of permissible explosives upon the roof more than balances any slight difference in sizes of coal produced.

The success of permissible explosives in Illinois mines shows that they have satisfied one of the great needs of the coal-mining industry. Their increased use throughout the United States has overcome many of the dangers which attended the use of black blasting powder. Their use ought to be extended so that the occurrence of mine fires, explosions, and accidents due to explosives will be reduced to a minimum. Permissible explosives stand for protection to life and property. Their use is no longer an experiment, but forms the basis for an effective and continuous campaign in accident prevention.

APPENDIX.

JOINT POWDER COMMISSION.

PROCEDURE IN TESTS WHEN MAKING CHANGE OF POWDER.

For the settlement of all powder questions that arise a joint powder commission is provided in the agreement between the operators and the miners. The procedure in all tests where a change of powder is desired is stated in the eighth clause of the agreement, as follows:[a]

> The price for powder per keg shall be $1.75, the same to be delivered at the face when so requested. The miners shall purchase their powder from the operators, provided it is furnished of standard grade and quality; and provided further, that other permissible explosives may be used when necessary for the safety of life and property. The permissible explosives shall be furnished at the same relative cost as black powder, the interest of operator and miner alike considered. In determining the powder for a mine, it shall be the purpose to select powder which shall give the best results to the miner and operator alike. A majority of the miners on the pay roll at any mine may file with the operator a written complaint against the powder being furnished by the operator. Such complaint must explicitly state the objections to the powder and must be signed by a majority of the miners. The operator may also file with the pit committee written notice of his desire to change the powder being furnished, stating his reasons therefor. Upon the filing of either complaint or notice as above stated, a test shall be arranged for as soon as possible, and such test shall be conducted under written regulations hereinafter provided for or the regulations may be prescribed by the joint powder commission hereinafter provided for. A joint State powder commission, who shall serve during the life of this agreement, shall be constituted, consisting of six members, three of whom shall be appointed by each executive board, respectively, of whom not less than one on each side, shall possess technical knowledge and all of whom shall possess either technical or practical knowledge of the use of powder in producing coal. Said commission shall have full control of all powder tests not settled locally, as herein provided. The commission shall be empowered to investigate the various phases of the powder question and may negotiate with powder companies for the establishment of standard sizes of powder and the proper branding thereof. It shall be the duty of the commission to eliminate entirely from cases of powder disputes the participation, openly or otherwise, of representatives of powder companies and shall by all lawful and proper means seek to secure for both operators and miners uniform deliveries of such powder as is selected as the most suitable in any given case.
>
> In case of a powder dispute arising at any mine as to kind of powder to be furnished under the provisions of this agreement, the dispute shall be first taken up locally by the interested parties and a local test made in order to determine whether the

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[a] Agreement by and between the Illinois Coal Operators' Association, the Coal Operators' Association of the Fifth and Ninth Districts of Illinois, and the Central Illinois Coal Operators' Association and the United Mine Workers of America, District No. 12, clause 8; continued in force April 1, 1916.

powder used or desired by either operator or miners is best suited or adapted for the use of the mine where the dispute arises. The local test shall be made in accordance with the following rules and regulations as nearly as possible and shall cover a sufficient time and tonnage to give the different powders tested a fair chance to determine their respective value: The powder to be tested shall be agreed upon by both parties to the controversy as being in the judgment of each best suited for use in the mine where the dispute arises, the interests of operator and miner alike considered. The kind of powder giving the best results in the opinion of the parties making the test shall be the powder used in the mine during the life of the contract unless otherwise directed by law or unless a radical change occurs in the character or condition of the coal seam or that a change of powder is mutually agreeable to both parties.

In the conducting of any local tests the following rules shall be observed and enforced, to wit:

1. Six members shall constitute the committee or commission for making any local tests, unless otherwise specifically agreed to by both operator and the miners; said committee or commission to be composed of three miners selected and authorized to represent the local and three men to likewise represent the operator. In case of additional members participating in any local test each side shall have equal representation.

2. The drilling of all holes shall be under the direct supervision of one miner and one operator, member of the committee or commission, during the conducting of any test.

3. One miner and one operator, members of this committee or commission, shall prepare all cartridges and keep a record of the measurements and weights of same, the results of the shots to be figured by weights of the powder used and the condition of the coal after being shot as a basis.

4. In no case shall the members of the committee or commission who drill or supervise the drilling of the holes have any knowledge of the powder to be used, or that has been used until after the shots have been exploded.

5. The members of the committee or commission shall tamp and fire or have direct supervision of the tamping and firing of all shots during any test.

6. A record shall be kept, giving the measurements of the face, the number of shots fired, the amount and the kind of powder used, together with the comparative condition of the place and shots.

7. The holes drilled shall be measured and inspected, when possible, by all members of the committee or commission and shall be placed as nearly as possible in the same direction and depth in order to insure as nearly as possible similar conditions and chances for the different grains or brands of powder to be tested.

8. In judging the results obtained from any test the interests of the miner and operator alike shall be considered, and if required by either party, a record of the tons of coal produced and the quality of same shall be kept.

9. The committee or commission shall have the right to require the sealing of any or all full or part kegs of powder in the mines during the conducting of any test and may adopt any other rule or method to insure that no other powder than the powder used by the committee or commission will count or figure in the results obtained by any test made by them.

10. The committee or commission shall eliminate entirely the participation, openly or otherwise, of men directly or indirectly representatives of any powder or powder company. In the event of a powder dispute arising, and the failure of either side to appoint its members of the committee or commission herein provided for within seven days after the complaint is filed, the State president of the organization failing to appoint its members locally shall make the appointment thereof promptly and the committee or commission so appointed shall proceed with the test as herein provided.

In case the committee or commission fails to agree after a test has been made locally, as herein provided, the said joint powder commission shall assume jurisdiction, and the whole data and records of the test shall be submitted to and be reviewed by it, and if all the conditions as above have been observed in conducting the test it shall take the matter up for final decision with power to make any further test it may deem necessary. It is understood and agreed that all the requirements of a local test as above must be complied with before the case can properly come before the joint powder commission.

Said commission may investigate shot firing devices, the merits of explosives other than powder, and the use of other mechanical agents than explosives for the production of coal, and make recommendations to the two organizations concerning the same.

It is understood that the question of package or kegs in which the powder is shipped be considered in the same way as the powder itself. That the joint powder commission will have access to the powder magazines at all times where disputes arise. That no new shipments of powder be stored on top of powder on hand, it being the intent to use the powder in the order in which it is received at the mine.

NOTE.—It is understood that the operator will not discriminate against any powder desired by the miners locally which meets the test as to grade and quality herein prescribed, provided it can be furnished at a competitive price and in sufficient quantities for the successful operation of the mine.

WORKING AGREEMENT BETWEEN OPERATORS AND MINERS.[a]

That section of the working agreement between the coal-mine operators and miners of Franklin County relative to the use of explosives reads as follows:

(*a*) Whether the coal is shot after being undercut or sheared by pick or machine, or shot without undercutting or shearing, the miners must drill and blast the coal in accordance with the State mining law of Illinois, in order to protect the roof and timbers and in the interest of general safety. Any miner who clearly violates the letter or spirit of this paragraph may be discharged.

(*b*) The system of paying for coal before screening was intended to obviate the many contentions incident to the use of screens, and was not intended to encourage unworkmanlike methods of mining and blasting coal, or to decrease the proportion of screened lump, and the operators are hereby guaranteed the hearty support and cooperation of the United Mine Workers of America in disciplining any miner who from ignorance or carelessness, or other cause, fails to properly mine, shoot, and load his coal.

(*c*) That all "bug dust" or machine coal cuttings when practically free from impurities be loaded out with the "snubbings" or other coal so as to produce a merchantable mine-run coal.

The above does not contemplate any change in the present method of handling "bug dust" or machine cuttings in Franklin County, or other mines where it is necessary to load same out before shooting the coal, as a protection against explosions or fire.

Where the operator desires the "bug dust" loaded out separately this shall be done by the miner working in the place during his regular shift at the regular tonnage price and the company shall furnish cars promptly to load same.

(*d*) Wherever it is practicable the miners shall shoot the coal with two pounds of powder or less. Where a dispute arises as to the practicability of shooting the coal with two pounds of powder, such dispute shall be taken up and settled by the two organizations as provided in this contract.

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[a] Working agreement by and between the Illinois Coal Operators Association, the Coal Operators Association of the Fifth and Ninth Districts of Illinois, and the Central Illinois Coal Operators Association, and the United Mine Workers of America, District No. 12, sec. 5.

(*e*) It is hereby agreed that the cost of firing shots during the life of this contract shall not exceed the cost per ton for the same work during the previous contract. It is understood that this clause does not mean that the operator can avoid paying for the work actually necessary to be done by the shot firers.

It is also agreed that there shall be no shot firers in mines where coal is undercut by hand or machines, except as mutually agreed. Where conditions in the past have necessitated shot firers they will be continued; where conditions develop that they are not necessary, they can be discontinued.

(*f*) The shot firers shall go into the mine two hours before the regular quitting time to satisfy themselves by examination and inspection of the shots to be fired that they have been properly placed and prepared. When examining shots the shot firers shall work single; when firing shots they shall work double.

(*i*) The miners shall continue to assume all responsibility heretofore resting upon them for the care of the working places and the proper character and placing of the blasting shots; and that in case of wet holes that will not stand if charged and tamped by the miners, the shot firers will attend to charging and tamping said holes.

STATE LAW IN REGARD TO SHOT FIRERS.

The Illinois law in regard to shot firers (Coal Mining Laws of Illinois, sec. 19) reads as follows:

SHOT FIRERS IN COAL MINES.

In all mines in this State where coal is blasted, and where more than two pounds of powder is used for any one blast; and, also, in all mines in this State where gas is generated in dangerous quantities, a sufficient number of practical, experienced miners, to be designated as shot firers, shall be employed by the company, and at its expense, whose duty it shall be to inspect and do all the firing of all blasts, prepared in a practical workmanlike manner, in said mine or mines.

The shot firers shall, immediately after the completion of their work, post a notice in a conspicuous place at the mine, in which shall be indicated the number of shots fired; also the number of shots they did not fire, if any, specifying the number of the room and designation of the entry, and giving reasons for not firing same. In addition they shall also keep a daily permanent record, in which shall be entered the number of shots or blasts fired, the number of shots or blasts failing to explode, and the number of shots or blasts that in their judgment were not properly prepared and which they refuse to fire, giving reasons for same; the record to be in the custody of the mine managers and to be available for inspection at all times by parties interested.

The superintendent or mine manager shall not permit the shot firers to do any blasting, exploding of shots, or do any firing whatever until each and every miner and employee is out of the mine except the shot firers, mine superintendent, mine manager, and man or men necessarily engaged in charge of the pumps and stables: *Provided, however*, that nothing in this section shall be construed to prohibit the employment in such mine of a reasonably necessary number of men during such time for the purpose of securing the workings in case of fire therein.

No miner or other person shall alter or change any drill hole, by increasing its depth, diameter or otherwise, after the same shall have been approved by the shot firer.

No shot firer, whether voluntarily, or by command or request of any person, shall fire any unlawful shot, or any shot which in his judgment, exercised as aforesaid, from his inspection thereof, made as aforesaid, shall not be a workmanlike, proper, and practical shot.

On firing ahead of the air the law (sec. 14, *d*) reads as follows:

> Away from the pillar for the mine bottom, crosscuts between entries shall be made not more than 60 feet apart without permission of the State inspector of the district and then only in case of "faults." When such consent is given, brattice or other means must be provided within 60 feet of the face to convey the air to the working place until a crosscut is opened up.
>
> When undercut or sheared, the entry, crosscut and room neck may be advanced concurrently, but not more than one cutting shall be shot in the room neck until the crosscut is finished; and after the entry has advanced 15 feet beyond the location of the new crosscut, only one shot shall be fired in the entry to two in either or both the crosscut and room neck at the same shooting time.
>
> When not undercut or sheared, the entry and crosscut may be advanced concurrently, but no room shall be opened in advance of the last open crosscut, and after the entry has advanced 15 feet beyond the location of a new crosscut only one shot shall be fired in the entry to two in the crosscut at the same shooting time.
>
> Not more than three shots shall be exploded at one shooting time ahead of the last open crosscut.

TOLERANCES FOR PERMISSIBLE EXPLOSIVES.

At a conference on June 7, 1915, between manufacturers of explosives and engineers and chemists of the Federal Bureau of Mines an agreement was reached providing for reasonable limits of variation or "tolerances" in the results of analyses and tests of permissible explosives. If these tolerances are exceeded by a given lot of any permissible explosive it is not permissible. The tolerances established, which were made effective July 1, 1915, have been published in Bulletin 96 [a] of the bureau, and are as follows:

> In order to define more exactly what is meant by the phrase "similar in all respects" in the definition of a permissible explosive, namely, "an explosive is called a permissible explosive when it is similar in all respects to the sample that passed certain tests by the United States Bureau of Mines, and when it is used in accordance with the conditions prescribed by this bureau," the following tolerances are recommended for field samples or manufacturers' samples of explosives, beyond which such lot of explosives can not vary and still be considered permissible for use in coal mines: *Provided*, That where the Bureau of Mines finds a sample which does not come up to the tolerance limits, the bureau shall simply declare that particular lot of explosives not permissible, and a copy of the notification to the consumer or owner shall be furnished the manufacturer, the notification to state that the explosive did not meet the tolerance requirements for moisture or ingredients, etc., as the case might be.
>
> *Chemical analysis.*—Moisture, to be fixed by a sliding scale of from 1½ per cent at zero to 4 per cent at 10 per cent of moisture in original sample, this tolerance being on total percentage of moisture in the explosive.
>
> Other ingredients (or their equivalents) in quantities not exceeding 60 per cent, according to curve (shown in fig. 17). For ingredients in quantities of 60 per cent or more, the tolerance shall be plus or minus 3 per cent: *Provided*, That the ingredients of a permissible explosive shall be considered to be those substances reported as found by the Bureau of Mines in the original sample of that explosive submitted for test as to its permissibility: *And provided further*, That an equivalent shall be considered to be a substance which would not materially alter the properties of the explosive and which would produce the same result as the original substance.

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[a] Storm, C. G., The analysis of permissible explosives: Bull. 96, Bureau of Mines, 1916, pp. 80–81.

Products of combustion (determined by Bichel gage tests).—The volume of poisonous gases from 680 grams of the explosive, including its wrapper, must be less than 158 liters, except that in case the first test yields 158 liters or more of poisonous gases per 680 grams of the explosive, including its wrapper, the average result of three tests agreeing within 5 per cent of each other shall be taken, and no explosive shall remain permissible when this average for poisonous gases exceeds the above standard limit.

Physical tests.[a]—

Rate of detonation (the average of three trials with Mettegang's recorder), plus or minus 15 per cent.

Unit deflective charge (the average of three trials with the ballistic pendulum), plus or minus 10 per cent.

Grams of wrapper per 100 grams of explosive, plus or minus 2.0 grams (average of four determinations): *Provided*, That the manufacturers shall submit samples of all different sizes of cartridges, to be considered as part of the original sample, the amount of wrapper to be determined for each size of sample: *And provided further*, That the tolerance as suggested shall be determined in comparison with the various diameters of samples as submitted with the original sample.

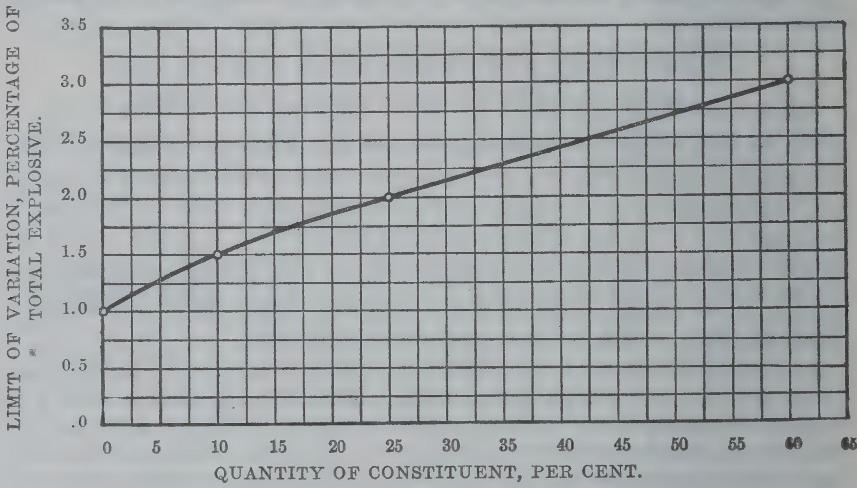

FIGURE 17.—Curve of limit variation in composition of permissible explosives.

Apparent specific gravity of cartridge, by sand, plus or minus 7.5 per cent (average of four determinations): *Provided*, That actual density shall be determined on cartridges of the same diameter as the standard: *And provided further*, That manufacturers shall be required to submit samples of all sizes.

Gas and dust gallery No. 1.—No ignition must be obtained in each of one or more trials. Note: In the retesting of permissible explosives by tests 1, 3, and 4,[b] the charges of the explosives fired will be reduced 10 per cent in weight from the weights originally used in order to eliminate any likelihood of a failure being due to the natural variations in the gallery conditions.

Pendulum friction test.—Each explosive must pass a test of 10 trials under the same conditions as originally tested, except that the height of fall of the wood-fiber shoe will be reduced by 10 per cent in order to eliminate any likelihood of a failure being due to the natural variations in test conditions.

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[a] For method of making these tests, see Hall, Clarence, and Howell, S. P., Tests of permissible explosives: Bull. 66, Bureau of Mines, 1913, 313 pp.

[b] Hall, C., and Howell, S. P., Work quoted, p. 303.

BUREAU OF MINES TESTS OF PERMISSIBLE EXPLOSIVES.

The conditions under which manufacturers may submit explosives for test by the Bureau of Mines to determine their permissibility, the fees charged for the tests, and the test requirements of permissible explosives are set forth in Schedule 1 [a] of the bureau.

CONDITIONS UNDER WHICH TESTS WILL BE MADE.

The conditions under which the Bureau of Mines will test explosives to determine whether they shall be placed on its list of permissible explosives are as follows:

1. The manufacturer or applicant desiring tests to be made is to deliver to the Bureau of Mines, Fortieth and Butler Streets, Pittsburgh, Pa., three weeks prior to date set for tests, 100 pounds of each explosive that he desires to have tested. He is to be responsible for the care, handling, and delivery of this material to the testing station, and if he desires he may have a representative present during the tests. In order to avoid duplication of work, it is requested that the smallest size of cartridge that he intends to place on the market be sent for these tests.
2. No one is to be present at or participate in these tests except the necessary Government officers at the experiment station, their assistants, the representative of the manufacturer of the explosives, or the applicant desiring tests to be made.
3. These tests will be made in the order of the receipt of the applications for them, provided the necessary quantity of the explosive is delivered at the experiment station by the date set, of which date due notice will be given by the Bureau of Mines.
4. A list of the explosives that pass certain requirements satisfactorily will be furnished to the State mine inspectors in the several States and will be made public in such manner as may be considered desirable.
5. The details of results of tests are to be considered confidential and are not to be made public prior to official publication by the Bureau of Mines.
6. From time to time field samples of permissible explosives will be collected, and tests will be made of these explosives as they are supplied for use in coal mines in the various States. Field samples collected in original shipping case will be tested for their permissibility and will be analyzed; the proportion of each ingredient of the explosive must agree, within a reasonable variation, with that in the original sample submitted for tests.

TEST REQUIREMENTS OF PERMISSIBLE EXPLOSIVES.

The tests will be made by the engineers of the Bureau of Mines in gas and dust gallery No. 1 at Pittsburgh, Pa., or in one of the identical galleries. The charge of explosive to be fired in tests 1 and 3 shall be equal in deflective power, as determined by the ballistic pendulum, to one-half pound (227 grams) of 40 per cent nitroglycerin dynamite in its original wrapper, of the following formula:

	Per cent.
Nitroglycerin	40
Nitrate of soda (sodium nitrate)	44
Wood pulp	15
Carbonate of lime (calcium carbonate)	1
	100

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[a] Fees for testing explosives and conditions and requirements under which explosives are tested: Schedule 1, Bureau of Mines, 1913, pp. 1–7.

Each charge shall be fired with an electric detonator (exploder or cap) strong enough to completely detonate or explode the charge, as recommended by the manufacturer. The explosive must be in such condition that the chemical and physical tests do not show any unfavorable results.

An explosive will be considered unsatisfactory if it is not chemically stable, if it shows leakage of nitroglycerin, or if it is in such condition that exudation of nitroglycerin would occur in handling or transportation.

A 680-gram (1½-pound) charge of explosive must not evolve 158 liters (5½ cubic feet) or more of poisonous gases as determined by gage tests. The poisonous gases that are likely to be evolved on explosion are carbon monoxide, hydrogen sulphide, and nitrogen oxides.

Explosives that are of such strength as to require more than 680 grams (1½ pounds) to satisfactorily break down coal under normal conditions of mining will be considered unsatisfactory. This is determined by the unit deflective charge (established with the ballistic pendulum) which shall not exceed 454 grams (1 pound).

An explosive will be considered unsatisfactory if in the course of the official tests two or more charges fail to detonate or explode completely, or if after two months' storage at the Pittsburgh experiment station two or more cartridges fail to detonate or explode completely when fired separately with a suitable detonator.

An explosive will be considered unsatisfactory if it is too sensitive to frictional impact (a glancing blow). This sensitiveness will be determined with the pendulum friction device with the shoe faced with fiber.

In order that the dust used in tests 3 and 4 may be of the same quality, it is always taken from the same mine, ground to the same fineness, and used while still fresh.

The following are the gallery tests to which are subjected the explosives that the Bureau of Mines is asked to place in the list of permissible explosives:

Test 1.—Ten shots each with the charge as described above, in its original wrapper, shall be fired, each tamped with 1 pound[a] of clay stemming, at a gallery temperature of 77° F., into a mixture of gas and air containing 8 per cent of gas (methane and ethane). An explosive is considered to have passed the test if no one of the ten shots ignites this mixture.

Test 3.—Ten shots each with the charge as described above, in its original wrapper, shall be fired, each tamped with 1 pound[a] of clay stemming, at a gallery temperature of 77° F., into 40 pounds of bituminous coal dust, 20 pounds of which is to be distributed uniformly on a wooden bench placed in front of the cannon and 20 pounds placed on side shelves in sections 4, 5, and 6. An explosive is considered to have passed the test if no one of the ten shots ignites this mixture.

Test 4.—Five shots each with a 1½-pound charge, in its original wrapper, shall be fired without stemming, at a gallery temperature of 77° F., into a mixture of gas and air containing 4 per cent of gas (methane and ethane) and 20 pounds of bituminous coal dust, 18 pounds of which is to be placed on shelves along the sides of the first 20 feet of the gallery and 2 pounds to be so placed that it will be stirred up by an air current in such manner that all or part of it will be suspended in the first division of the gallery. An explosive is considered to have passed the test if no one of the five shots ignites this mixture.

EXPLOSIVE NOT TO BE CONSIDERED PERMANENTLY PERMISSIBLE.

It must not be supposed that an explosive that has once passed the required test and has been published in lists of permissible explosives is always thereafter to be considered a permissible explosive, regardless of its condition or the way in which it is used. Thus, for example, an explosive named in the permissible list, if kept in a moist place until it undergoes a change in character, is no longer to be considered a permissible explosive. If used in excess of the quantity specified (1½ pounds), it is not, when so used, a permissible explosive. And when the other conditions have been met, it is not a permissible explosive if fired with a detonator of less efficiency than that prescribed.

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[a] Two pounds of clay stemming is used with slow-burning explosives.

Moreover, even when all the prescribed conditions have been met, no permissible explosive should necessarily be considered as *permanently* being a permissible explosive, but any permissible explosive, when used under the prescribed conditions, may properly continue to be considered a permissible explosive until notice of its withdrawal or removal from the list has been officially published, or until its name is omitted from a later list published by the Bureau of Mines.

Furthermore, the manufacturers of a permissible explosive may withdraw it at any time when introducing a new explosive of superior qualities. And after further experiments and conferences the Bureau of Mines may find it advisable to adopt additional and more severe tests to which all permissible explosives may be subjected, in the hope that through the use of such explosives only as may pass the more severe tests, the lives of miners may be better safeguarded.

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A limited supply of the following publications of the Bureau of Mines has been printed and is available for free distribution until the edition is exhausted. Requests for all publications can not be granted, and to insure equitable distribution applicants are requested to limit their selection to publications that may be of especial interest to them. Requests for publications should be addressed to the Director, Bureau of Mines.

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PUBLICATIONS THAT MAY BE OBTAINED ONLY THROUGH THE SUPERINTENDENT OF DOCUMENTS.

Bulletin 10. The use of permissible explosives, by J. J. Rutledge and Clarence Hall. 1912. 34 pp., 5 pls., 4 figs. 10 cents.

Bulletin 51. The analysis of black powder and dynamite, by W. O. Snelling and C. G. Storm. 1913. 80 pp., 5 pls., 5 figs. 10 cents.

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Technical Paper 107. Production of explosives in the United States during the calendar year 1914, with notes on coal-mine accidents due to explosives, compiled by A. H. Fay. 1915. 16 pp. 5 cents.

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